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Plantation Crops in Tropical Agriculture

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Of the thousands of different products of tropical agriculture, most are consumed locally; only a few hundred enter into international trade. Of these, only a small number are of vital importance to the Western world and of fundamental significance to the economies of the areas where they are produced. Most of them are plantation-grown, even though not in all cases to the same extent as formerly. A majority are tree crops, and their production is well distributed throughout the tropical world, as suggested by a tabulation of the principal exporters of ten important crops:

	Crop	*Principal exporter*
AFRICA	Groundnuts (peanuts)	French West Africa
	Cocoa	Ghana
	Oil palm products	Nigeria
ASIA	Tea	India
	Rice	Burma — Thailand
	Rubber	Malaya
	Coconut palm products	Philippine Is.
LATIN AMERICA	Sugar	Cuba
	Coffee	Brazil
	Bananas	Ecuador — Honduras

Except for groundnuts and rice these crops are, or have been in the past, known as plantation crops.

The importance of a single export crop to the economies of producing countries varies greatly. For example, in a large country like India, with other sources of income, tea accounts for only about one fifth of the value of all exports; but for smaller (essentially one-crop) Cuba the value of sugar exports often runs around four fifths of the export total. Even in diversified Brazil exports of coffee amount to approximately three fourths of the total value of all exports. And, of course, some of the secondary tropical exporting countries are more heavily dependent upon a single crop for their foreign exchange than its leading exporter.

Products of the tropics have played a notably useful role in Western civilization since ancient times, and continue to do so today. At first they were few in number and available only to the wealthy. Gradually one-time luxuries became necessities. Over several recent centuries the list of commodities of tropical origin has undergone considerable change. Some have disappeared for all practical purposes, other persist in trade but have a greatly diminished importance, while some of the most important today have achieved their stature in relatively recent times.

'Plantation crops', which are predominantly tropical, have a long, interesting, and significant history. For the most part they are utilized outside the areas where they are grown, especially in the Western world. Whereas in the past they contributed substantially to the development of

Western economies, today plantation crops, as a group, are an important key to progress in many an underdeveloped area of the tropical world. They are the means by which numerous countries earn exchange for the purchase of non-agricultural goods.

Most plantation crops possess unique and exclusive advantages in that they thrive only in their special environment. Typical crops of the rainy tropics which cannot be grown successfully in temperate climates are bananas, cocoa, coconuts, oil palms, rubber and spices. Coffee is grown on tropical uplands and cannot be grown outside the tropics. Rice and tea, however, flourish in humid sub-tropical areas, and even in temperate zones. Sugar cane can be grown outside the tropics but costs of production are higher where optimum natural conditions are not present. Various fruits (including citrus) are grown in the tropics but are not confined to them. Maize, cotton and tobacco are in the same category. Perennial crops predominate in the list of major tropical crops, but rice is by far the most important annual, being the basic food for about half the world's population.

When the British created the Office of Secretary of State for the Colonies in 1768 it was popularly known as the Plantation Office, a carry-over from early colonization activities in North America. But as overseas possessions came to be better known as colonies the term ' plantation ' acquired a more restricted meaning. Today the Commonwealth Economic Committee periodically issues a statistical review of sugar, tea, coffee, cocoa, spices, tobacco and rubber under the heading *Plantation Crops* and explains the linkage as recalling the time ' when they were produced for the most part on " plantations " overseas '. These crops are still cultivated on plantations but not exclusively or predominantly so. Rubber and cocoa are notable examples of crops now grown by peasant farmers on small holdings in greater volume than on plantations.

Despite the many questions raised in recent years as to the appropriateness of the plantation system under today's changed conditions (see WICKIZER, 1958), plantations are still able to assume the financial, if not the political, risks inherent in tree culture much better than the small individual grower. They are better informed and better able to judge future market requirements. They can ordinarily command the capital necessary to set up large-scale units, provide the required machinery and equipment, and employ technical and operational personnel of competence. They are able to organize for efficient production all along the line, at the same time providing a regularity of supply and uniformity of quality that cannot be achieved otherwise for many commodities. In short, the modern, enlightened version of the plantation has much to offer to a world avidly seeking advancement.

AGRICULTURAL DEVELOPMENT IN THE TROPICS

Europeans learned about tropical products, especially the value of spices, partly as a by-product of the Crusades, but it was not until the latter half of the fifteenth century, when West-European access to the East became increasingly difficult, that they took action which was soon to open the period of modern commerce.

Domination of the geographically favoured Italian city-states in trade with the East, the expensive and uncertain land and sea routes involved, and the encroachment of the Ottoman Turks on the lands that lay along possible routes, all gave impetus to the search for alternatives. When Portuguese explorations along the African coast finally culminated in direct all-sea contact with India, the Italian trade monopoly was broken and Asiatic land routes largely abandoned.

Meanwhile, by the opening of the sixteenth century America had been discovered and the Atlantic displaced the Mediterranean as the European contact with the tropical world. Economic leadership shifted from Italy to Portugal and Spain; agricultural development in tropical lands under European guidance was soon to begin.

European demand for a few tropical products inspired explorations for shorter or safer trade routes, but the lure of gold or other riches was ever-present. Wars and political rivalries of the time emphasized the importance of establishing beachheads or permanent settlements on newly discovered strategic, or potentially profitable islands or mainlands. Colonization led naturally to agricultural development. Over many centuries peoples of the north middle latitudes brought, at one time or another, almost every part of the tropics under their political control*. Only in recent years has the trend been reversed.

In the early days of colonization, tropical crop production for export was facilitated by the establishment of plantations, owned and managed by Europeans; later, in the opening up of new areas, the indigenous population was encouraged to grow certain crops for export. The plantation system continued to be used and expanded for the important crops requiring substantial capital investment. But there were also examples, especially during the last few generations, of native and plantation production growing up side by side, e.g. sugar in the West Indies and rubber in southeast Asia.

Many crops originally found in one part of the tropics were transplanted to another, frequently meeting with conditions of production more favourable than in their original homes. Production of some of today's important tropical crops, e.g. rice, sugar, coconuts, bananas, cotton, was already well established when Europeans first undertook their long voyages in search of spices. Others when first encountered by Europeans were known and used to some extent at their points of origin, but in a manner so different from present-day usage that their production and market were limited, e.g. coffee and oil palm products. The crops that came to be desirable in the advanced Western temperate-zone countries were transplanted or introduced in widely scattered parts of the world.

Botanical gardens, first established in the seventeenth century, were responsible for the discovery and introduction of numerous tropical products over a period of roughly two hundred years. They were early manifestations of interest in scientific agriculture and were often the forerunners of agricultural departments, established much later. As colonial-type agriculture emerged from an experimental stage and markets were created for tropical

*For an able summary account of some of the repercussions of this development, see an article by the late Sir HAROLD TEMPANY (1953).

produce in Western countries, the botanical gardens played a significant role in the development of the colonies*. By 1900, however, it was thought that this migration of crops had ended. Writing in 1908, Willis held (see Willis, 1914)

> . . . most of the new products that can possibly be brought in are now introduced . . . Almost everything of value in tropical agriculture is now in the hands, somewhere or another, of Europeans, Americans, Chinese or Japanese, and in starting any new product in any country a fierce competition will have to be met from countries already growing that product.

Along with the crops went a migration of peoples to provide the labour force needed, or to supplement that already available. The Negroes went involuntarily to the New World from Africa, beginning about 1500. Their descendants remain in the tropical and sub-tropical regions of America as well as in the United States. East Indians went to various parts of tropical Asia and Africa much earlier but also came to America after the abolition of slavery in the first part of the nineteenth century. Chinese migrated to southeast Asia and islands of the Pacific even before these areas were opened to direct trade contacts with Europe. Likewise the Japanese went south to Pacific islands and to South America in modern times, particularly in the present century. European communities grew up in the highlands and climatically favourable lowlands in the tropics, almost from the beginning of permanent settlement.

Pioneering entrepreneurs interested in the production of tropical crops for which there was a booming demand in Western countries had considerable choice of location. Where comparable soil and climatic conditions were found for a particular crop, selection of location depended heavily upon adequacy of the labour supply, but also upon transportation or access to markets. From the seventeenth to the early nineteenth century, when African slave labour was available, the American tropics held the leading position; there was ample European venture capital, labour as needed, and transport was relatively short and easy. Sugar colonies and sugar production dominated the scene. Abolition of the slave trade in the British and French West Indies in the first part of the nineteenth century, however, resulted in a shift of attention to the Asiatic tropics, where the indigenous population frequently provided a settled, docile and plentiful labour supply. Still not all of the desired conditions of plantation agriculture were present. A most important one—access to markets—was improved with the opening of the Suez Canal in 1869 and following the introduction of the steamship. Ceylon and Java were among the first of the Asiatic islands to be developed as producers of a variety of tropical crops, and the chief beneficiaries at this time.

Technological changes also were responsible for shifts in emphasis upon crops and centres of production. A very early crop, indigo, which was imported into Europe in ancient times and was cultivated in the Americas [especially in Central America, but at one time (1750–1790) in the United States] and Asia (India and Java), lost ground with the invention of aniline

*The British founded a garden at Oxford as early as 1632, the Dutch established the first colonial garden at Capetown in 1694, a private garden was established near Philadelphia in 1730, an experimental farm near Savannah in 1733, and the Royal Botanic Gardens at Kew were established in 1760, followed by the first government garden in a British tropical colony in St Vincent in 1780 (see Masefield, 1950). It was not until the period 1820–60, however, that other gardens were established in British Guiana, Trinidad, Jamaica and Ceylon.

dyes in 1859 and their introduction on a commercial scale in the 1890s. European demand for soap, the development of the margarine industry in the 1870s, and the needs of the tin plate industry in the 1890s, led to increased demand for vegetable fats, particularly oil palm products. This demand stimulated production in West Africa and later the Netherlands Indies and Malaya, to the benefit of native producers. It provided a source of cash income for African peasants. The later development of the industry in southeast Asia, however, was on a plantation basis, employing indigenous labour.

At times in the present century success in expanding the output of important tropical export crops caused prices to fall so low that they provoked political intervention, and the imposition of state or international controls, e.g. coffee, rubber, sugar, tea. Regularization of production to support prices became the major objective of commodity policy. But during the post-1945 period shortages and high prices rather than surpluses characterized most tropical commodities, and only in recent years have some been threatened with a recurrence of problems of excess supplies. The adjustment of output to consumption requirements remains a problem even if not currently an acute one.

Since 1945 and the loss of European colonies in Asia, attention has shifted from southeast Asia to Africa. Some foresee there a development of tropical export agriculture comparable to that which took place in Asia during the preceding hundred years. But times have changed, nationalistic tendencies are becoming general in underdeveloped countries, and desirable patterns of progress are by no means agreed upon.

EVOLUTION OF THE PLANTATION AND TRADE IN ITS PRODUCTS

As a form of agriculture, plantations became important as Europeans began their energetic exploration of new lands, started settlements, and endeavoured to exploit the resources of these new-found areas. But even before America was discovered and an important plantation centre was established in the West Indies, the Portuguese operated sugar plantations on the island of Sao Thomé off the West Coast of Africa. Sugar started and paced the development, transformation and migration of the plantation system to most parts of the tropics.

Historical records make clear the long dominance of, and preference for, sugar as the principal plantation crop of the West Indies. Despite numerous efforts, and official encouragement of the introduction of new crops, no other tropical crop ever assumed anything like the importance of sugar. There were cocoa, coffee, cotton, pimento, ginger and indigo plantations. Usually these crops were not grown in combination. In the British islands there was little diversity; in the French possessions there was more; but throughout the West Indies sugar dominated, as it does to this day.

Early in the nineteenth century the relative importance of the Caribbean area and its products began to decline as world events re-shaped international relationships of all kinds. During many decades following the abolition of slavery, subsidized beet sugar became increasingly important in total world supplies. In 1839 beet production was only about five per cent of the total but by the opening of the twentieth century it accounted for more than

half. Only at this time was the long-term trend reversed and the cane proportion began to increase. So discouraging were market prospects around the 1870s that Caribbean growers began to give some attention to alternative crops—in the British West Indies coffee, pimento, ginger and (later) bananas received attention in Jamaica; cocoa in Trinidad and Grenada; arrowroot in St Vincent; and citrus fruits in Dominica and Montserrat.

Since 1800 changes in the character and volume of international trade were the result of several important developments both in old countries and new. In Europe population growth was rapid, faster than additions to indigenous food supplies. ' Surplus ' population was partly absorbed through industrialization, but also by emigration to the new world. As the younger countries were settled by these emigrants their demands for equipment and supplies provided an outlet for European manufactured goods. Technological advances in Europe made possible production in excess of local market needs. Export outlets were sought in the newly settled, less developed countries. In turn, the capital and equipment supplied from old country sources made possible impressive developments in transportation, opening vast areas in new countries for the production of food needed by industrialized Europe. The opening of the extensive temperate plains in the latter half of the nineteenth century was certainly a most significant development.

But the intensification of tropical cultivation to serve foreign industrial markets was almost equally so: at this time southeast Asia became the dominant factor in the production and export of tropical commodities. When the West Indies enjoyed the greatest concentration of plantation agriculture the then most important colonial products were well represented there, but the temperate world also obtained supplies produced by peasant farmers in the Orient who sold their output to trading companies for marketing. Plantation agriculture became important in south and east Asia only after European interest abandoned sole reliance upon trading companies for direct participation in the growing of numerous tropical crops which could find a ready market in Europe or America.

In the Asiatic tropics early development of export crop production took the form of encouraging local farmers to grow special crops in addition to those necessary for their own subsistence whereas in the West Indies the introduction of outside capital generally meant the establishment of plantations. Conditions of tenure were determined by the need for capital and operations were ordinarily possible only if outside labour could be obtained. Plantation owners and managers up to the opening of the present century were little concerned with social issues; cheap labour and easy access to markets seemed the most important factors in garnering profits. There was scant appreciation of scientific methods in agricultural production, although investigation of the tropical crops themselves began late in the last century.

The underpinning of the sugar plantations of the West Indies was shaken early in the nineteenth century. Wars, competition from the Far East and from beet sugar in Europe, rising transportation costs, abolition of the slave trade, heavy capital expense for installing the new steam-powered mills,

years of poor weather and spreading plant diseases all conspired to this end. The individual estate manager was obliged to seek labour from neighbouring estates, steam engines were worth installing only if a large enough acreage was available to be cut, shipping and marketing difficulties multiplied. A tendency toward consolidation of plantations or estates made its appearance, as was often to happen later when other tropical crops fell under adverse circumstances.

It was primarily the rising cost of labour in the West Indies, after the abolition of slavery, that led to the shift of export crop production from the American to the Asiatic tropics. The more important crops produced there were the newly appreciated tree crops such as coffee, cinchona, tea, and finally rubber, all of which required some years to come to maturity and bearing, substantial financing during the waiting period, and (usually) capital equipment for processing in preparation for the market.

Following Ceylon, the Netherlands Indies came to the fore after the opening of the Suez Canal in 1869 and abolition of the Culture System a year later. Under the Culture System, introduced in 1831, peasant producers were obliged to plant one fifth of their land in crops designated by the government, e.g. sugar, coffee and indigo. They were required to deliver their output to government warehouses, partly in payment of taxes. It was a system designed to force native production of export crops, but its success was limited and the system was finally supplanted by private enterprise in the form of plantation production.

While improved access to the routes of world commerce was a basic reason for the rise of the Asiatic tropics in European trade, it was not the only one. Southeast Asia ultimately supplanted the American tropics in leadership because of two developments earlier in the century which discouraged enterprise in the western hemisphere, i.e. abolition of slavery and the revolutions which won independence for most Latin American countries.

Early crops cultivated for export from Asiatic sources were the traditional ones, i.e. sugar, tobacco and coffee, already grown extensively in the western hemisphere. Tea was also becoming more important in the latter part of the nineteenth century but Asiatic production was not in competition with American. Gradually the list of crops was extended as the demand for industrial raw materials grew. Emphasis shifted to rubber, vegetable oils and fibres. At the same time petroleum, tin and other minerals were entering the trade from southeastern Asiatic sources. When the Caribbean area was the principal supplier of tropical commodities, most of the products receiving attention more recently were unimportant.

Although the plantation system reached its highest state of development in the European colonies of southern and eastern Asia before 1939, the profound political changes since then have led to a new interest in Africa, the only remaining continent still subject to strong European influences (see WICKIZER, 1951). Except for cocoa in Ghana, oil palm products in Nigeria, and groundnuts in French West Africa (all predominantly peasant-produced), African countries are not yet, however, leading exporters of the major tropical crops. While perhaps not currently receiving the same attention as Africa, the older established centres of plantation agriculture in

southeast Asia and in Latin America continue to lead in producing and exporting the majority of tropical crops. In Asia these are tea and pepper (India), rubber (Malaya), coconut products and abacá (Philippines), cinchona and kapok (Indonesia); in Latin America the products are coffee (Brazil), sugar (Cuba), bananas (currently Ecuador). These examples of course do not suggest the range of tropical crops grown in the countries mentioned.

PLANTATION CROPS AND ECONOMIC DEVELOPMENT

The exchange of tropical products for those of the temperate zone was one of the earliest forms of international trade. It still has importance but is far overshadowed by the trade among the industrialized nations outside the tropics. Individual tropical crops such as coffee, rubber and sugar, however, are among the leading commodities in world trade, and many others (tobacco, rice, vegetable oils, tea and tropical fruits) are among the 20 to 30 commodities of all kinds that account for over one third of all international trade. Over four fifths of the world's production of such commodities as coffee, tea, cocoa and rubber is exported from tropical countries to the industrial West. Over one third of the production of bananas, sugar cane and coconut products is similarly marketed. Only the basic cereals such as rice and maize are consumed primarily in the areas of production, although the volume of exports is huge in comparison with the majority of tropical crops. Despite the inroads of peasant growers, plantation production of export crops continues to overshadow every other form.

Whether plantation-produced or grown by small holders, the demand for some tropical crops is still increasing while the markets for others are shrinking. Some of the popular crops are not in any sense essential, but they have become part of the Western pattern of life. Others continue to be valued as strategic raw materials.

If temperate-zone demand for tropical crops were to change radically (which seems unlikely except under extremely abnormal price conditions or as the result of technological changes), the balance of trading and political relationships with countries producing them would be seriously upset. Efforts to encourage and assist underdeveloped tropical countries seem predicated upon the continued willingness (and ability) of industrialized nations to purchase their exportable produce.

Development of most tropical countries, at least in the initial stages, depends heavily upon the expansion and improvement of export crop production and such expansion implies the successful development of markets. Some of the tropical crops (e.g. coffee, tea, cocoa) seem to have an assured future; others (e.g. cinchona, some of the fibres and perhaps rubber) seem to face declining demand as conditions change in the importing countries. Such developments would not be a new phenomenon, but only a continuation of shifts that have occurred almost since the beginning of worldwide trading.

The path to economic development is one of more effective utilization of natural and human resources with the objectives of raising living levels and increasing human happiness. Progress in this direction by means of changes of a voluntary or semi-voluntary nature is slower but probably more

secure than by the ' forced-march ' approach of a regimented economy. Cultural changes that accompany economic growth by a natural process of stimulated evolution are likely to be reflected in more liberal political and social institutions and attitudes. The importance attached to potential changes in underdeveloped countries by an influential group [see Committee for Economic Development (1956)] in the United States is suggested by the statement:

> In the long run the profound internal transformation now going on in the underdeveloped countries could determine the political shape of the world . . . . the climate in which Western democracy will have to live and grow will be greatly affected by the kinds of societies that finally emerge in the underdeveloped world.

United Nations (1955) experts recently noted the expanded networks of transportation and communication in the post-1945 period in underdeveloped countries, but suggested:

> Perhaps the most significant advance . . . . lies not so much in the physical expansion of productive capacity *per capita* as in the evolution of a social climate favourable to economic development. The change in social philosophy, especially in countries which have only recently acquired national independence, is of revolutionary proportions; the vision of economic and social progress is taking its place alongside religion and language as a basis for social integration. Its effects are visible not only in the market place but in political and social institutions.

It is not clear whether the ' change in social philosophy . . . of revolutionary proportions ' applies primarily to political leadership or is more general. Certainly there are numerous examples of greater output or improved productive efficiency in tropical agriculture secured only at the expense of social disorganization, and resisted by peasant farmers.

Physical expansion of productive capacity *per capita* is desirable on the assumptions that such capacity is needed, that it can be utilized for increased output, and that this greater output can be produced efficiently and competitively. More efficient production of crops is a generally accepted objective of agricultural development in tropical countries. But it can seldom be achieved without modifications in existing social structures. Necessary changes must be effected slowly if development plans and programmes are to meet with success. Political and social repercussions accompany and follow almost every move designed to change the agricultural sector of the economy and the lives of those dependent upon it—from introduction of the simplest form of mechanization to redistribution of land holdings.

As the less advanced countries develop and become able to supply many of their needs through local enterprise, it may be assumed that their demands for certain types of imports will decline. Meanwhile, however, the generally beneficial effects of an enlarged volume of international trading should contribute to the development process. Important tropical export crops, largely but not exclusively plantation-produced, have a vital role to play in the evolving world economy. There is good reason for the most effective organization for the production of these crops to be a major concern of statesmen, politicians and agricultural experts in tropical countries.

(*Received February 1958*)

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Mango Propagation by a "T" Graft Method

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The accepted method of propagating mangoes in Trinidad is by 'inarching' or as it is also called 'approach grafting'. This is one of the oldest methods used for the propagation of mangoes and records of its use in India date back to ancient times.

The inarching method consists of the growing of rootstocks in containers for about 12 to 18 months until they have attained a size of at least $\frac{3}{8}$ in. to $\frac{1}{2}$ in. in diameter when they are grafted on to scions while the latter are still attached to the mother tree. The containers with the rootstock are brought near to the scions by means of a platform or scaffold built under each tree at a suitable height (*Figure 1*). The graft takes three months to heal, and during this period, they are severed from the mother tree in two stages. Before planting out in the field, the plants are kept in a cool place for another month. It thus requires a minimum of approximately sixteen months to produce a mango plant by this method.

It will be realized that the building of these scaffolds, the growing of rootstocks for such a long period, and the carrying out of the grafting operation on these elevated platforms make this method of grafting slow, cumbersome and expensive.

The scions required for grafting are selected branches, and the number of plants that can be produced is limited by the availability of such branches on existing mother trees. A large number of fully matured trees occupying a considerable acreage is thus required to produce plants in economic quantities by this method and any planning for production has to be carried out several years ahead.

On account of these drawbacks alternative methods have been investigated, and in many countries inarching has been replaced by chip, shield or patch budding. Within recent times veneer grafts have become popular in the United States of America (Popenoe, 1956).

In Trinidad, however, alternative methods have been tried with limited success, and on account of the very low percentage of takes there was no change over from the existing method of inarching.

Investigations were thus initiated to determine the cause of failure of methods reported to be successful in other countries. Several trials of budding and grafting were carried out using different stages of growth of stock and scion, and different wrapping material. After correcting some of the causes of failure, a fair percentage of takes was achieved by patch budding and terminal wedge grafts on one-year old stocks growing in the field, and side veneer grafts on four-month old stock growing in containers and in the field.

Figure 2. Four months old mango rootstock

Figure 1. Julie mango tree with inarched grafts and scaffolding

With knowledge gained from these trials a new method has been devised for the propagation of mangoes—The ' T ' Graft Method—which has the advantages of rapidity, low cost, and ease of production.

DESCRIPTION OF METHOD

The ' T ' Graft Method consists of making a ' T ' cut in the bark of the stock, and inserting between the wood and the bark a prepared terminal shoot. The scion is then tied firmly to the stock and the entire graft is wrapped with plastic tape.

Preparation of stock

Seeds of a vigorous variety of seedling mango are collected and sown in a germinating medium (cocopeat, sawdust etc.) and after sprouting they are removed to prepared nursery rows in the field. In Florida the hard seed covering is opened (LYNCH and MUSLARD, 1955) and the seed is separated from the husk before placing it in the germinating medium; this is done to reduce the period required for the seeds to sprout.

After four months the nursery seedlings, which should have attained a circumference of $\frac{3}{4}$ in. to 1 in. at 3 in. above ground level, may be grafted (*Figure 2*). This is the minimum size of stock on which a ' T ' graft can be done with reasonable success.

Preparation of scion

The scions are selected from terminal shoots which have attained a growth of 3 to 4 in. and are at least $\frac{1}{2}$ in. in circumference, with well matured growth on which terminal buds are swollen. The scion must always be slightly thinner than the stock. Thus, in selecting scions for grafting it is necessary to know the size of the stocks available.

Selected scions are defoliated 8 to 10 days before cutting off from the mother trees (*Figure 3*). This is done to allow the petiole stubs remaining on the shoot to drop off naturally, resulting in the formation of a protective seal at the points of abscission. Scions used without this pretreatment have resulted in a high percentage of failures, as a result of fungal infection through the cut petiole.

A sloping cut is made to the scion starting $\frac{1}{2}$ in. from the base of the terminal bud and extending downward to at least 1·5 in., ending with a point on the other side of the scion (*Figure 4*).

Grafting

At a point at least 3 in. above ground level, a ' T ' cut is made in the bark of the stock. The horizontal cut of the ' T ' is made half way round the circumference of the stock, and the vertical cut is made 1·5 to 2 in. long. The bark at the top end of the vertical cut is lifted sideways and downwards extending to half way down the length of the cut. On the top side of the horizontal cut, at the point where the two cuts of the ' T ' meet, a chip of bark is removed to facilitate a closer fit between stock and scion (*Figure 5*).

The prepared scion is inserted between the bark and wood of the stock, and pushed down along the vertical cut of the ' T ' until the top end of

Figure 1. Scions prepared for grafting

Figure 2. Julie mango branch with defoliated terminal scions

Figure 5. Rootstock with chip of bark removed above 'T' cut

Figure 6. Scion tied to rootstock

Figure 7. Scion wrapped with plastic tape

Figure 8. One month after grafting

Figure 10. Three months after grafting

Figure 9. Two months after grafting

the cut surface of the scion is in contact with the cut surface left on the stock where the bark was removed from the top of the horizontal cut.

The scion is then tied firmly to the stock with raffia by making a knot near the region of the horizontal cut (*Figure 6*). The entire graft including the terminal bud is finally wrapped with resinite tape or polythene 0·0035 in. × ½ in. (*Figure 7*).

Over 80 per cent successful grafts have been obtained by the use of this method.

After-care

Twenty one days after grafting the wrapping material is removed from the terminal bud only, and about one third of the growth of the stock above the graft is cut back. The scion at this time is beginning to shoot from its terminal bud (*Figure 8*). After two months a fair amount of foliage is produced by the scion, and at this time the stock is cut back farther (*Figure 9*). At the end of the third month a final cut is made to the stock at the top end of the grafted region, and all wrapping material is removed. By this time the scion has grown and produced a crown of foliage large enough for the plant to be transplanted (*Figure 10*).

Figure 11. Lifted plants for transplanting

Lifting

The percentage of mortality in mangoes on lifting and transplanting is comparatively high. Trials carried out on lifting have shown that by lifting the plant in two stages, the percentage lost by this operation is reduced to a minimum. In the first stage, one month before lifting the plant, at a distance of 3 to 4 in. from the plant the soil is removed from one side to a

depth of 8 to 10 in. and the tap root is severed. The soil is replaced, and the plant is given a dressing of sulphate of ammonia at the rate of 1 oz per plant. After the one-month period has elapsed the second stage of lifting the plant from the ground with a ball of earth is carried out. The ball of earth is wrapped with pieces of jute bagging material, and the plant is ready for immediate transplanting, or may be left in a cool place where it can be stored for weeks with a little watering (*Figure 11*).

DISCUSSION

By the ' T ' Graft Method a minimum of seven months to produce a fair sized plant is required. This is a saving in time of at least nine months when compared with the inarching method.

A grafter can complete at least 100 lateral grafts by this method in a working day as against 36 by inarching.

The cost of production by the ' T ' Graft Method is estimated at 22*c*. per plant. The inarching method as carried out at St Augustine Station, a Governmental Agricultural Station for the propagation of plants in Trinidad, costs 95*c*. (B.W.I.) per plant—an appreciable difference. The cost of production for 1 000 plants by both methods is given for comparison below.

(*a*) By inarching method

	$ *c.* (B.W.I.)*
Seeds and bamboo pots	157.80
Preparation of soil, potting and watering	332.68
Scaffolding	293.30
Grafting, including untaping, cost of tape, twine and tar	174.39
Total	957.17

(*b*) By ' T ' Graft Method

Seeds and preparation before planting	28.00
Preparation of land for planting	7.00
Planting, weeding and manuring	33.60
Grafting, including preparation of scions, untaping, cutting back and cost of tape	51.25
Lifting	105.00
Total	224.85

* 1 B.W.I. Dollar = 4*s* 2*d*

The above details of costs of production were prepared in January 1957 when the average rates for labour were as follows:

Men — $3.00 per day
Women — $2.70 ,, ,,
Boys — $2.46 ,, ,,

Much of the success of the ' Lateral Bark Graft ' depends on the stage of growth of the stock. In Florida, rootstocks two to three weeks old are used with good success in chip budding (Lynch and Muslard, 1955). In the ' T ' Graft, however, it is necessary to have the bark and wood of the stock well developed, but the plant must remain in an active state of growth. This is noticeable by a new flush of leaves or by cutting the bark when a distinct ooze of plant sap from the cut surface can be seen. At this stage the bark lifts easily.

The type of wrapping material used is important. Resinite CT–4 Clear Budding Tape (size $\frac{1}{4}$ in. × 0·004 in.) and polythene of the same gauge have given excellent results as against raffia and waxed tape. Good results have also been reported with the use of resinite tape in the budding of cocoa (Topper, 1956).

There seems to be some difference in the rate of growth of different varieties of mangoes used as rockstocks at least in the nursery stage. Three varieties locally known as 'vert', 'rose' and 'teen' were used as rootstocks in these investigations. Of these 'rose' was the most vigorous and gave the best results on grafting. Further investigations are necessary to determine the most suitable rootstock.

SUMMARY

A new method—the 'T' Graft Method—of mango propagation is described. The method consists of making a 'T' cut in the bark of the stock and inserting between the bark and the wood a prepared scion from a terminal shoot.

The cost of producing plants by the new method is 23 per cent of the cost by inarching. The output of plants is greater and the period required to produce a plant is less than half the time required by inarching.

ACKNOWLEDGEMENTS

My grateful thanks are due to Dr B. G. Montserin, Deputy Director of Agriculture (Research), for his encouragement and keen interest during the course of these investigations; to Mr St George Cooper, Senior Agricultural Officer, for helpful suggestions on reading the script and to Mr R. Dowlat for the skill displayed in carrying out the grafting trials.

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Mango Propagation—A Modified System of Approach Grafting

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The only practicable large-scale method of mango propagation in Trinidad previously in general use was the standard approach graft method using one-year old rootstock seedlings in bamboo pots. This method is cumbersome and expensive and takes about eighteen months to produce a plant suitable for planting in the field. By the method described hereunder plants are produced in six months and at a 75 per cent reduction in cost.

PREPARATION OF ROOTSTOCKS

Seeds of a vigorous mango variety are sown in well prepared seedbeds covered with peat, sawdust or coconut fibre dust to provide a loose moisture-retentive rooting medium. In about six weeks after sowing suitable seedlings for grafting are obtained. At this stage they are 6 to 9 in. tall, reddish in colour and are still subsisting on the food reserves in the seed (*Figure 1*).

The seedlings are carefully lifted and the seed and small roots covered in moist moss which is then wrapped in polythene to prevent desiccation. The polythene wrapping is held in position by means of jute string, the ends of which are left about six inches long. These free ends are used to tie the rootstock on to the tree for grafting (*Figure 2*).

GRAFTING

The prepared seedling is tied on to the selected parent tree near to suitable scion material. Approach grafting is done in the usual way for mangoes, care being taken to match stock and scion in thickness and age. A sloping cut about one inch long is made across the stock 3 in. from the base. This is closely fitted on to a cut made half way through the scion (*Figure 3*) and the graft is held close together by tying with raffia (*Figure 4*). Raffia is used in preference to other material as it is sufficiently elastic to allow for growth without causing constriction, provided that it is not spun but used as a flat band. The graft is protected from the weather by taping with a $\frac{1}{2}$ in. wide polythene strip (*Figure 5*).

POTTING

A healed union is effected in four weeks during which time no attention whatsoever is needed. The scion is then severed from the parent tree. Raffia ties, tape and polythene wrapping are removed and the plant is potted. It is important that the moss is left around the seed since this reduces the shock of removal from the parent tree.

The young plant must be kept in partial shade for one month to harden and root into the potting medium. It is then ready for planting in the field.

Figure 2. Seedling prepared for grafting

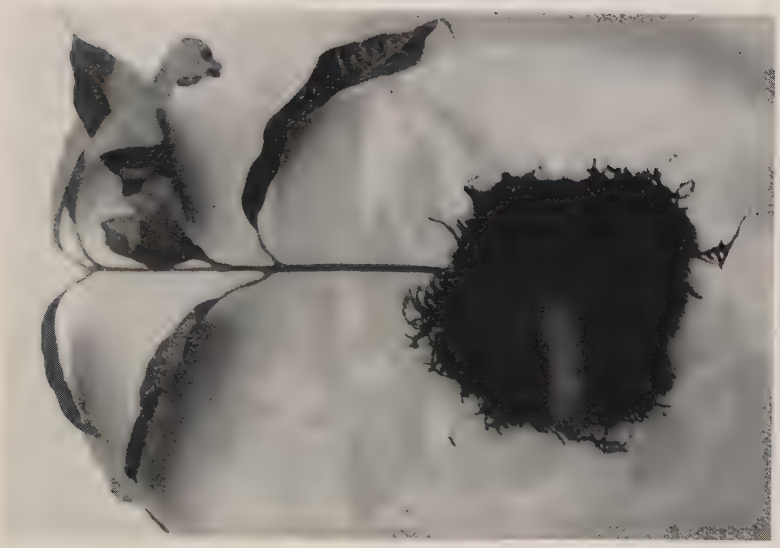

Figure 1. Seedling at suitable stage for grafting

Figure 4. Stock and scion tied with raffia

Figure 3. Stock and scion ready for tying together

Figure 6. Grafted plants ready for field planting

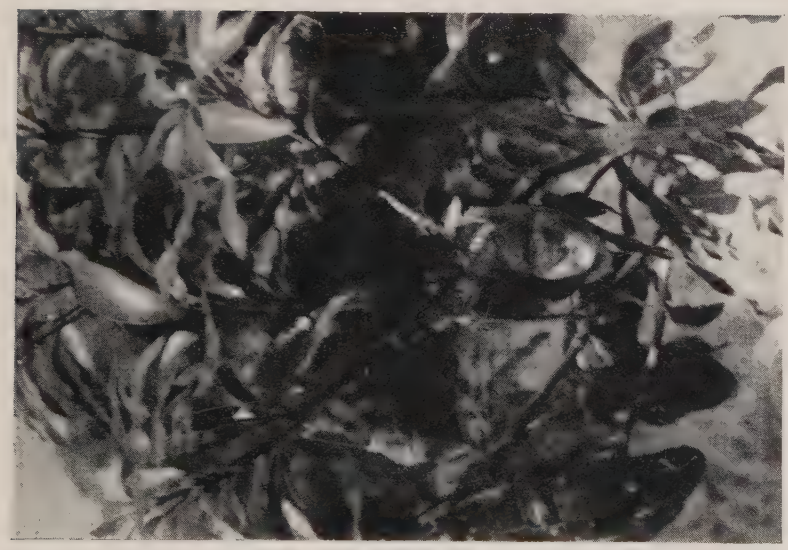

Figure 5. Completed grafts on tree

DISCUSSION

This method is now being used successfully for propagation of the varieties Julie, Graham, Bombay and Pierre Louis. The percentage of successful grafts varies with the variety, being 90 per cent for Julie and nearly 100 per cent for Graham. A skilled worker can comfortably put on 50 grafts in a day. The cost of producing a plant by this method is approximately one shilling.

SUMMARY

A rapid, inexpensive method of approach grafting for mangoes is described. Six week old seedlings with the seeds surrounded by moss and wrapped in polythene are used as rootstocks. The method is being used for extensive production in Trinidad.

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A Method for the Rapid Propagation of Cassava Cuttings

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Considerable work has been carried out on the breeding of cassava (*Manihot* spp.) for improvement of yield and resistance to cassava mosaic virus in West Africa (Auchinleck, 1937; Kincaid, 1948) and in East Africa (Storey, 1938; Nichols, 1946). The method used by breeders has been to grow seed produced by a particular cross for a period of at least six months by which time cuttings can be taken from the stem for multiplication during the following season. This method allows only six 8-in. long cuttings to be obtained from one seedling under West African conditions. The plants produced from these after a further 9 or 12-month period total about 100 cuttings, sufficient for a variety trial using micro-plots.

A technique developed at Moor Plantation, Ibadan, in connection with the heat inactivation of cassava mosaic virus in the growing plant (Chant, 1958), showed that it was possible to produce from three to six plants within four weeks of planting, thereby increasing the number of cuttings produced by the end of the second year to about 500.

The object of the present investigation was to define the technique and to study the effect of various hormone treatments on the establishment of the new plants.

MATERIALS AND METHODS

The plant material used throughout the experiments was a hybrid variety of cassava, (*Manihot utilissima* Pohl.) GCH7. Uniform 6-in. cuttings taken from stands in the field were planted in boxes in the screenhouse (*Figure 1*). After they had sprouted, the shoots were allowed to grow until they had attained a height of 6 or 7 in. when they were excised from the parent cutting, care being taken to remove also a very small portion of heel, i.e. tissue from the node of the parent cutting (*Figure 2*). The cuttings were then dipped for 15 minutes, 2, 6 or 24 hours in one or other of the following hormone solutions: α–naphthalene acetic acid (INA) or indolyl butyric acid (IBA) at concentrations in water of 10, 40 and 80 parts per million or in mixtures of the hormones at 5, 20 and 40 parts per million of each one.

The quick dip method (Evans, 1951) of immersing the cuttings for periods of 1 to 10 seconds in 50 per cent alcohol solutions of IBA and INA at concentrations of 1, 3, 6 and 9 mg/ml was also attempted.

After hormone treatment the shoots were planted at 2-in. spacings in seed boxes (40 per box) in a heat-sterilized potting medium of one part sand and one part soil before being transferred to a propagator in the screenhouse. A copper fungicide was applied as a spray three times weekly to prevent the development of moulds and other fungal pathogens.

Figure 1. Box of field-type cuttings sprouting in the screenhouse—the cuttings on the left have just had their green shoots removed

Figure 2. Green shoots removed and trimmed ready for hormone treatment

A further experiment was carried out to assess the effect of the type of potting medium on the root development of the stems.

Three weeks after treatment records were made in all experiments of the number of roots produced per plant and their average length.

EXPERIMENTAL RESULTS

It was found that the removal of the young shoots stimulated the development of buds in the axils of the other nodes (of the parent cutting) and also dormant buds in the axil of the node from which a shoot had been removed.

Table 1 shows the number of green shoots removed over a period of 26 days from a total of 400 cuttings (no hormone treatment given).

Table 1. Number of green shoots removed from 400 cassava cuttings over a period of 26 days

No. of parent cuttings	*Date*							*Total*
	17/4	*20/4*	*24/4*	*27/4*	*2/5*	*8/5*	*13/5*	
400	122	186	206	195	158	125	141	1133

After 21 days, 86 per cent of the original 400 parent cuttings were still alive and had produced more top growth while, out of the 1133 green shoot cuttings, 75 per cent had survived and were developing normally with a slightly slower growth rate as compared to the shoots still left on the parent cuttings but at a faster growth rate than seedlings grown under the same conditions.

Therefore from 400 cuttings a total of 1196 plants were produced.

In *Table 2*, the numbers of cuttings surviving after various hormone treatments are shown.

Table 2. Percentage of young green cassava shoots surviving (out of 80) three weeks after removal from parent cuttings, and hormone treatment

Hormone conc. p.p.m.	*Period of immersion*			
	15 min	*2 h*	*6 h*	*24 h*
10 IBA	95	100	55	67
40 IBA	67	—	—	—
80 IBA	67	—	45	—
10 INA	100	90	90	67
40 INA	—	—	72	—
80 INA	—	—	50	—
5 IBA + 5 INA	77	90	—	60
20 IBA + 20 INA	77	40	—	—
40 IBA + 40 INA	67	45	40	22
Control (water only)	80	75	—	67

There is a tendency for the percentage of cuttings surviving to decrease with the longer periods of immersion and the higher hormone concentrations. The quick dip method proved quite unsuitable as it resulted in the death of almost all the cuttings treated due to rotting at the base of the stem.

Tables 3 and *4* show the effect of the weakest concentrations of hormone on the number of roots developed and their length (40 shoots per treatment).

It will be seen from the data in these tables that hormone treatment results in a greater root development on the young green stems. *Figure 3* shows the effect of the 5 IBA + 5 INA mixture and 10 INA compared with the control three weeks after treatment.

The effect of the type of potting medium is shown in *Table 5* where it is seen that, although sand is the best medium from the point of view of survival of cuttings and the actual number of roots produced, sawdust is the best medium in respect of the length of roots produced.

Table 3. Mean number of roots produced on green cassava shoots three weeks after removal from parent cuttings, and treatment with various hormones (40 shoots per treatment)

Hormone conc. p.p.m.	*Period of immersion*				
	15 min	*2 h*	*6 h*	*24 h*	*L.S.D. (P = 5%)*
10 IBA	6·9	8·5	6·9	10·6	0·42
10 INA	6·8	8·0	6·2	8·9	0·41
5 IBA + 5 INA	8·0	9·5	—	16·9	0·57
20 IBA + 20 INA	8·9	7·8	—	9·8	0·48
Control (water only)	7·1	6·8	—	6·5	0·36
L.S.D. (P = 5%)	0·38	0·46	0·34	0·64	

Table 4. Mean length (cm) of roots produced on young green cassava shoots three weeks after removal from parent cuttings, and treatment with various hormones (40 shoots per treatment)

Hormone conc. p.p.m.	*Period of immersion*				
	15 min	*2 h*	*6 h*	*24 h*	*L.S.D. (P = 5%)*
10 IBA	6·1	8·3	5·9	6·2	0·46
10 INA	6·4	6·8	6·2	7·9	0·39
5 IBA + 5 INA	6·7	8·0	—	6·6	0·51
20 IBA + 20 INA	5·1	5·5	—	6·6	0·50
Control (water only)	6·0	6·5	—	5·9	0·43
L.S.D. (P = 5%)	0·46	0·73	0·42	0·51	

(a) (b) (c)

Figure 3. Green shoots three weeks after removal from the parent cutting: (a) *no hormone treatment,* (b) *5 p.p.m. IBA + 5 p.p.m. INA,* (c) *10 p.p.m. INA*

Table 5. Effect of potting medium on establishment and subsequent growth of young cassava shoots treated with 5 IBA + 5 INA for 2 hours

Potting medium	*No. of cuttings survived*	*Mean root length*	*Average no. of roots*
Sand	40	12·9	8·1
Sawdust	27	14·7	6·6
1 part sand plus 1 part sawdust	20	6·2	7·0
Coconut fibre	35	14·2	3·8
L.S.D. ($P = 5\%$)		0·64	0·78

DISCUSSION

The methods outlined in this paper should be of value to cassava breeders who wish to obtain rapid multiplication of new hybrids for field trials. With care in handling the material it is shown in *Table 1* that at least three-fold multiplication of plants can be obtained from each 6-in. cutting. Hormone treatment is of value in stimulating root development but care must be taken to ensure that only low concentrations (about 10 p.p.m.) are used as higher concentrations appear to have a deleterious effect on the establishment of the green shoots.

The type of potting medium also appears to have a considerable bearing on the survival of the cuttings but further investigation is necessary of this aspect of the work.

SUMMARY

A technique is described for the rapid multiplication of cassava by means of excising the young green shoots from the parent cutting. This stimulates the development of dormant buds and if care is taken in handling the excised shoots they will produce roots and grow in the normal way.

Hormone treatment assists the production of roots although an adverse effect on the survival of the cuttings may be produced when the hormones are used in concentrations above 10 p.p.m.

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The Rapid Artificial Drying of Cocoa Beans and Chocolate Flavour

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During the work on fermentation and drying, a portion of the beans from each of many fermentations (Howat *et al.*, 1957a) was dried in the sun (6 to 10 days), and the remainder in the dryer (14 to 24 hours), and with regard to flavour two points of interest emerged:

(*a*) Beans dried in the sun made up into satisfactory unconched chocolate

(*b*) Beans dried artificially made up into fruity unconched chocolate.

It should perhaps be explained that conching (Chatt, 1953) is an important process in chocolate manufacture, just prior to tempering and moulding, the conche receiving its name from the shell-like shape of some of the original machines. The tank of the conche has a hot-water jacket and a roller is moved to and fro over the bed, every one or two seconds, by a crank, the temperature and duration of conching lying between fairly wide limits from one manufacturer to another (Chatt, 1953). Among the many beneficial changes that occur in conching, there is a loss of volatile constituents, and when conching removed the fruity flavour and left a quite satisfactory chocolate, it seemed likely that the compound responsible was volatile in nature.

EXPERIMENTAL

Steam distillations were carried out from a 1 000 ml flask; convenient quantities were 100 g of minced bean or cotyledon, 20 g of shell, and 200 or 400 ml of water at the beginning of the experiment. As long as standard conditions are maintained (Morton, 1938) the titration of the acid distillate, after a given volume has been collected, is a measure of the volatile acid originally present in the sample being distilled. For instance, 400 ml of distillate contain about 40 per cent of the volatile acid originally present, when the initial volume in the distilling flask (augmented during distillation by the condensation of steam) is 400 ml. Detection of volatile aliphatic acids was by paper chromatography, using the method of Reid and Lederer (1951):

Solvent system, *n*–butanol saturated with an equal volume of 1·5N ammonia

Indicator solution, 0·4% (w/v) bromocresol purple in a 1:5 (v/v) dilution of BP formalin in ethanol, pH brought to 5·0 by the addition of 0·1N caustic soda.

Acids appear as yellow spots on a blue background when the sprayed paper is held in an atmosphere saturated with ammonia vapour from its dilute aqueous solution.

RESULTS

A set of distillation curves is given in *Figure 1* for various samples of whole beans and the volatile acidity is seen to be higher for beans dried at high temperature and for a short time in the dryer, than for those dried in the sun for periods of up to 7 or 8 days*. The former give rise to the fruity-tasting unconched chocolate while the latter are generally satisfactory. For different box fermentations, where the duration varied from 6 to 8 days, it is not possible to see a significant change in the volatile acidity. A sample of typical West African beans (heap fermented and sun dried) has a lower volatile acidity (M5, *Figure 1*).

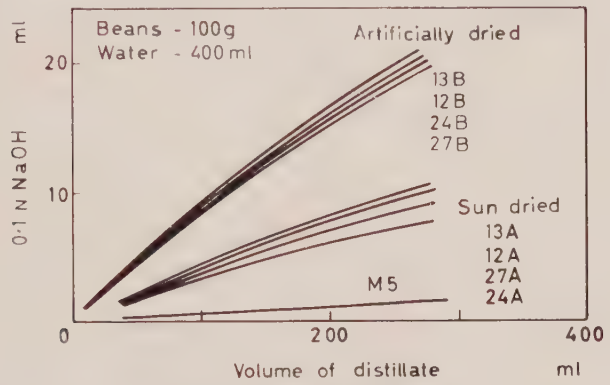

Figure 1. Steam distillation curves

The shell of the bean accounts for about 12 per cent of the weight of the whole bean and contained 25 to 30 per cent of the volatile acid. Examination of the distillates by paper chromatography showed that they contained acetic acid, as was expected, whether from the whole bean or from the shell or cotyledons separately. No other volatile acid was detected and the semi-quantitative nature of the chromatographic technique indicated that no other volatile acid could be present in a significant amount. No volatile acid at all could be found in the fresh unfermented bean on its removal from the pod.

The fruity beans therefore have a relatively higher content of acetic acid, but this higher acidity need not necessarily be responsible for the unwanted fruity flavour—the two effects of high acidity and fruity flavour merely running parallel.

Acetic acid was added in increasing quantities to samples of standard chocolate (while liquid) with which it was mixed, and after moulding, tasted. The characteristic fruity flavour was evident in all samples containing more than a certain amount of acid, which was of the order (3 mg per gramme of cotyledon) found by distillation in the equivalent quantity of ' fruity ' cotyledons.

The volatile acidity is determined before roasting though the acid was added to finished chocolate, but it was shown that the loss of acetic acid in roasting is less than 5 per cent of that present.

* For full particulars see Howat *et al.* (1957a).

DISCUSSION

In the first day of fermentation yeasts convert much of the sugar in the pulp into ethyl alcohol, which attains a concentration of 3 to 4 per cent. Acetic acid bacteria develop rapidly thereafter and for the next 2 or 3 days predominate over all the other types (Rombouts, 1952). It has been shown above that acetic acid is absent from the pulp, testa and cotyledon of fresh beans at the time of their removal from the pod. As fermentation proceeds, the acetic acid produced in the pulp must pass (Howat *et al.*, 1957b) through the testa and into the cotyledon, which could account for the fall in the pH of the cotyledon from its initial value of about 6·6 (*Figure 2*, bulk fermentation).

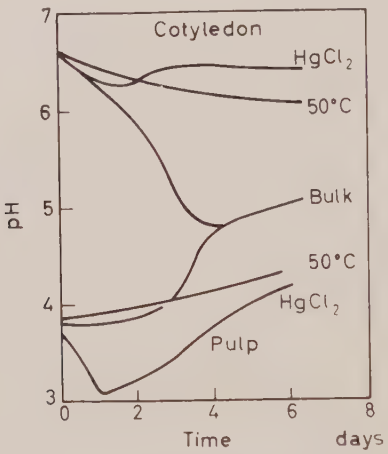

Figure 2. Change in pH of pulp and cotyledon in fermentation

Initially the pulp of the bean has a pH of about 3·8, due to citric acid, to which the testa is impermeable (Quesnel, 1957); during fermentation it is gradually lost in the sweatings (Hardy, 1925). The citric acid (a relatively stronger acid) is lost from the pulp simultaneously with the production of acetic acid and the net observed effect is a rise in pH.

Beans treated with mercuric chloride, which kills micro-organisms, follow a different pH/time pattern (Howat and Powell, unpublished), the value for the cotyledon remaining almost constant as fermentation proceeds, and that for the pulp showing little net change.

A similar behaviour is observed in laboratory experiments where beans are kept at 50° C, a temperature at which acetic acid bacteria do not survive, as well as in small scale fermentations by the 35°/50° method (Wadsworth and Howat, 1954) when care is taken to transfer the beans rapidly from a sterile pod to a sterile beaker. In the absence of these precautions the pH/time curve is similar to that from a bulk fermentation. When acetic acid bacteria are absent, therefore, the pH of the cotyledon does not fall.

The pH/time pattern of a bulk fermentation with the beans killed by previous freezing follows only a slightly modified course—acetic acid

production would be unimpaired by freezing and chemical reactions in the cotyledon are seemingly unrelated to it.

Under the low temperature conditions of sun drying the loss of acetic acid by evaporation is greater than during the short period and high-temperature artificial drying. This is not as surprising as it appears at first sight: the air temperature inside a dryer may be as high as 80°, but water has a high specific heat and a high latent heat of evaporation and the wet fermented bean has a moisture content of about 53 per cent. Only towards the end of drying, then, will the bean temperature approach the air temperature, the shell temperature approximating more closely to the air temperature earlier in the drying process. In support is the observation that although artificially dried whole beans contain more acetic acid than sun dried, a smaller proportion of this acid is in the shell.

CONCLUSIONS

(*1*) Cocoa beans dried rapidly contain more acetic acid than sun dried beans from the same fermentation. It is present in both shell and cotyledon and is distributed in the ratio of about 1:2.

(*2*) These beans give rise to chocolate with a fruity flavour, unless adequate conching, sufficient to eliminate it, is included in the process of manufacture. The loss of acid on roasting is small and less than 5 per cent of the total.

(*3*) Direct experiment has confirmed that acetic acid does cause the fruity flavour.

(*4*) Rapid drying, within the limits specified, has no other adverse effect on flavour. This has been referred to before (Howat *et al.*, 1957a).

(*5*) Should drying times be further reduced to less than 14 hours, some manufacturers might find it necessary to modify the process of conching in a manner which would require increased expenditure on plant and/or power and which they would be reluctant to do. A reduction to less than 14 hours could possibly prove undesirable on other grounds—lack of chocolate flavour, excessive brittleness of shell, etc., but no experiments in this range have been reported.

SUMMARY

The rapid artificial drying, as distinct from the slow artificial drying or sun drying, of cocoa beans, after fermentation, causes an unwanted fruity flavour to appear in the subsequent chocolate. This is removed when adequate attention is given to the conching operation of factory processing, but it should be stressed that the degree of attention given does vary considerably between manufacturers. The flavour has been shown to be due to the presence of an excess of acetic acid and an explanation of the way in which this arises is given.

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A Fertilizer Experiment on Dasheen

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Although *Colocasia esculenta* (*L.*) Schott is widely grown and is an important food crop, particularly in Polynesia and the Pacific Islands, very little experimental work appears to have been carried out with it. In Hawaii, for example, a few small trials carried out more than 20 years ago indicated some response to fertilizers but no fertilizer experiments appear to have been carried out within recent years. In view of this dearth of information, it seems worthwhile to report the results of an exploratory fertilizer trial carried out at the Imperial College of Tropical Agriculture on a type of *Colocasia esculenta* known locally as dasheen.

This experiment was commenced by Walker (1957), a post-graduate student at I.C.T.A. in part fulfilment of the requirements for the D.T.A. (Trin.). The design, analysis and summary of the results were prepared by the author.

Description of Experiment

The fertilizer treatments consisted of all combinations of presence and absence of:

Sulphate of ammonia (20·6%N)	1 oz per plant
Triple superphosphate (47% P_2O_5)	1 oz per plant
Muriate of potash (50% K_2O)	$\frac{1}{2}$ oz per plant
Farmyard manure (FYM)	6 lb per plant

which were applied at planting.

Two kinds of planting material (suckers and tops) were also tested in all combinations with the fertilizer treatments, since it had been suggested that size of the planting material influenced the yield (Paine, 1939; McClelland, 1924). The suckers consisted of small setts without cut surfaces while the tops were larger setts and had been cut.

This 2^5 factorial experiment was arranged in randomized blocks of 8 plots each using partial confounding of some of the higher order interactions; there were 2 replications. The plots consisted of 28 plants spaced 3 ft $\times$ 3 ft, with double guard rows.

The experiment was laid out on four cambered beds which were ploughed and levelled before planting. The soil was classified as River Estate Fine Sand—an approximate 1:1 mixture of fine sand and silty clay, acid and low in available nutrients. Planting took place at the end of October 1956 and the experiment was harvested in June 1957. During the dry season (February–April) the crop was grown under irrigation (1 in. at weekly intervals) provided by overhead sprinklers.

RESULTS

The mean responses to each of the five factors, together with their responses in the presence and absence of each of the others are shown in *Table 1*. The responses to nitrogen and to FYM were clearly significant at the 5 per cent level, while there was some indication of a smaller response to potash. In general, there was little response to phosphate. Observations on vegetative growth also showed a response to nitrogen.

Table 1. Differential responses (cwt per acre)

Factor	Mean response	Suckers	Tops	Responses with: Nitrogen Abs.	Nitrogen Pres.	Phosphate Abs.	Phosphate Pres.	Potash Abs.	Potash Pres.	FYM Abs.	FYM Pres.
	(±3·68)					(±5·20)					
Planting material (Tops—suckers)	+3·3			+3·8	+2·8	+4·2	+2·3	+8·7	−2·1	+9·6	−3·1
Nitrogen	+18·4	+18·9	+17·9			+16·2	+20·6	+23·7	+13·1	+26·2	+10·6
Phosphate	+2·3	+3·3	+1·4	+0·1	+4·5			+5·8	−1·2	+8·9	−4·2
Potash	+5·6	+11·0	+0·2	+10·9	+0·3	+9·1	+2·1			+5·6	+5·6
FYM	+9·1	+15·4	+2·7	+16·9	+1·3	+15·6	+2·5	+9·1	+9·1		

Mean yield: 63·51 cwt per acre SE per plot ±14·71 cwt per acre or 23·5 per cent (41 d.f.).

It was suspected that nitrogen might have a deleterious effect on the quality of the crop, but flavour tests carried out by Walker failed to detect any differences. Perhaps quality is only affected when excess nitrogen is used.

An interesting feature of these results is the behaviour of the two kinds of planting material. The tops yielded slightly more than the suckers on the average. This superiority was more pronounced (although not significant at the 5 per cent level) in the absence of FYM or potash, but this order was not maintained when these manures were present. These interaction effects are also manifested by significant responses to potash and FYM (11·0 and 15·4 cwt per acre respectively) with the suckers but little response with the tops. The responses to nitrogen were very similar with both planting materials.

The presence of FYM reduced the responses to both nitrogen and phosphate, the former reaching significance ($26{\cdot}2 - 10{\cdot}6 = 15{\cdot}6$ compared with $2{\cdot}02 \times \sqrt{2} \times 5{\cdot}20 = 14{\cdot}85$ at the 5 per cent level). Such negative interactions may be expected between fertilizers supplying the same nutrient, and it was therefore surprising that a similar effect was not observed with potash and FYM. Further investigation indicated, however, that with the suckers alone, there was a corresponding negative interaction although it did not reach significance, the responses to potash in the absence and presence of FYM being 16·0 and 6·0 cwt per acre respectively.

This additional analysis involved the computation of the yields, freed from block effects, for the eight treatment combinations involving the three factors: planting material, potash and FYM. Adjustment for block effects was necessary because the interaction between these three factors had been partially confounded; it was carried out by reconstructing the yields from the estimated treatment effects, as suggested by Yates (1937). Although three factor interactions are frequently not required in exploratory work, this situation illustrates the value of partial confounding, if available, as an insurance when, as often occurs, there is no *a priori* information on interactions.

The low mean yield of 3·2 tons per acre was probably due in part to insufficient irrigation during the marked dry season and perhaps also to late planting since the usual time in Trinidad is May–June at the commencement of the rains.

SUMMARY

This paper presents the results of a 2^5 exploratory trial on a type of *Colocasia esculenta* known in Trinidad as dasheen, testing nitrogen, phosphate, potash, farmyard manure and two kinds of planting material (tops and suckers). Responses to nitrogen, potash and farmyard manure were observed with the suckers but the only appreciable response of the tops was to nitrogen. There was some indication of other interactions, notably between nitrogen and farmyard manure.

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The Effect of Temperature and Moisture during Storage on the Viability of Grass Seed

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Within recent years research work on grassland improvement in the West Indies has been concerned with the establishment of pastures from seed. One aspect of the work on grass seed has been methods of storage. This note puts on record the results of an experiment to study the effects of temperature and moisture conditions during storage on the viability of grass seed which was carried out at the Imperial College of Tropical Agriculture during the period January 1955 to February 1957.

This experiment was carried out successively by a number of post-graduate students (Davies, 1955; Russell, 1956 and Sykes, 1957) to whom full acknowledgement is made. The present summary, however, is the responsibility of the author.

THE EXPERIMENT

Seed of Mexican grass, *Ixophorus unisetus*, was used in this experiment because of its availability and its high initial viability (85 per cent) when harvested in January 1955. It was stored under six moisture conditions each at four different temperatures as given in *Table 1*. Seed stored at the specified moistures was placed in test tubes containing predetermined quantities of dehydrating agents covered by cotton wool; the tubes were then sealed. The seed stored without moisture control was kept in paper packets; the relative humidity of the air was 70 to 100 per cent. Moisture determinations were made on all seed at the end of the experiment. Room temperature varied between 68° and 86° F, average 80° F. There were two replications.

Germination tests were carried out on all the stored seed every three months during the first year and every four months during the second year; the actual dates are shown in *Figure 1*. In each test, samples of 50 seeds were placed in saturated conditions between damp filter papers in covered butter dishes. The number of seeds germinating was counted on three or four occasions (during a period of about 3 weeks) until no further germination was noted.

RESULTS

Analysis of the germination percentages from each test showed that both the main effects of temperature and moisture and their interaction were consistently highly significant. *Figure 1* shows the changes in the mean germination percentages with time in storage under the various conditions

of temperature and moisture. In spite of the variation from test to test it is clear that, as observed elsewhere (Myers, 1952; Bass, 1953), the cooler and drier conditions favoured the maintenance of viability whereas conditions of high moisture and high temperature were most destructive.

The variability in the detailed results is probably due in part to the tests being carried out by different operators. The same operator tended to give fairly consistent results as shown, for example, by the graphs for 45° F in *Figure 1*. Greater objectivity could have been secured by the provision at the outset of precise instructions for the selection of the seed for the tests and for the unambiguous recognition of germinated seed. Some of the

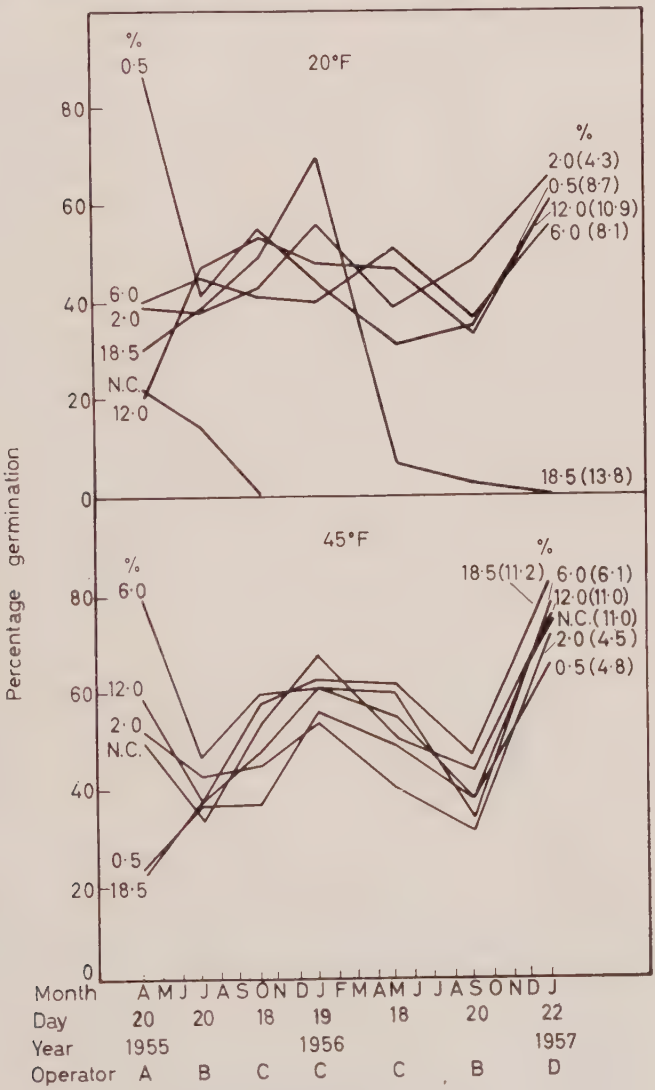

Figure 1, part 1: see continuation, p 210

irregularities in the results may also be explained by the breakdown in the moisture control which the final moisture determinations revealed had occurred during the experiment, probably when the successive samples were withdrawn. The average moistures of the samples at the conclusion of the experiment are shown in brackets in *Figure 1*. The use of separate sealed tubes for each sample would have overcome this difficulty. Despite these shortcomings the main features of the results seem to be clear.

The results are summarized in *Table 1*, where the mean values of the germination percentages transformed to degrees are given for the first three and the last three tests, these groups of tests having two operators in common

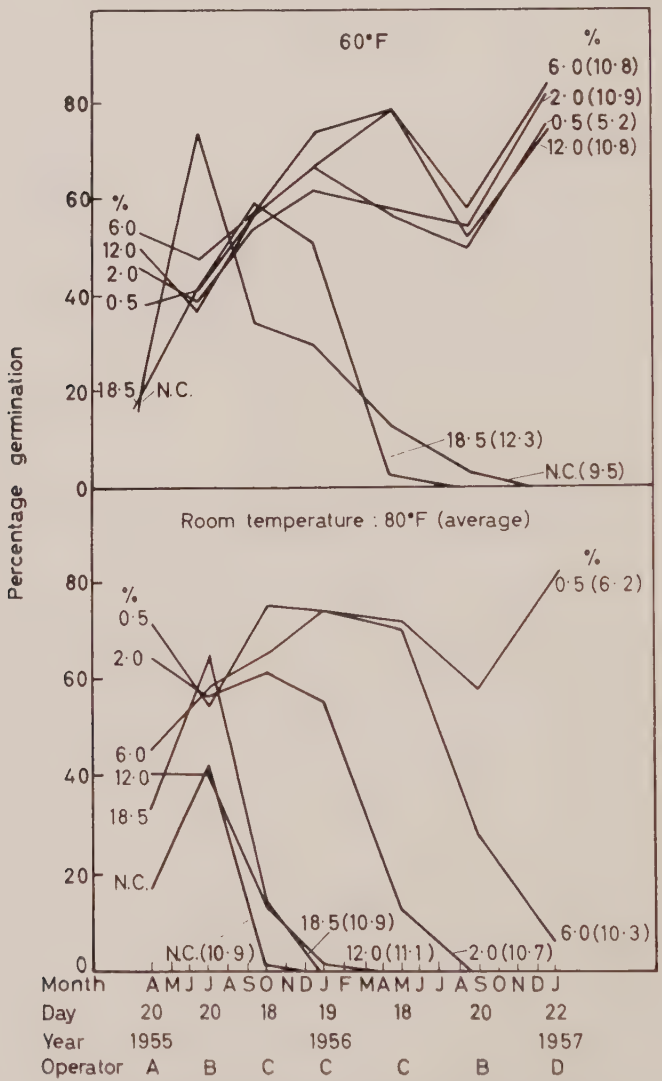

Figure 1, part 2. Effect of temperature, percentage moisture and time in storage on the viability of Mexican grass seed (Ixophorus unisetus)

Table 1. Viability of seed stored under various conditions of temperature and moisture

Mean values of germination perceniages transformed to degrees.

	(a) *Tests carried out in April, July, October, 1955*					(b) *Tests carried out in May, September, 1956 and January, 1957*					(c) *Difference* (a) — (b)				
Initial moisture (%)	*Temperature* (°F) 20	45	60	80*	*Mean*	*Temperature* (°F) 20	45	60	80*	*Mean*	*Temperature* (°F) 20	45	60	80*	*Mean*
	± 2·11				±1·05	±3·48				±1·74	±4·39				±2·19
0·5	52·4	34·2	42·3	55·6	46·1	40·3	45·0	51·6	58·5	48·8	+12·1	−10·8	−9·3	−2·9	−2·7
2·0	39·2	42·5	42·9	51·6	44·1	45·7	43·3	54·1	7·0	37·5	−6·5	−0·8	−11·2	+44·6	+6·6
6·0	40·3	52·0	46·7	49·0	47·0	43·8	49·1	59·7	32·8	46·3	−3·5	+2·9	−13·0	+16·2	+0·7
12·0	38·0	43·5	43·8	33·9	39·8	43·2	48·3	56·4	0·0	37·0	−5·2	−4·8	−12·6	+33·9	+2·8
18·5	38·8	38·2	38·6	36·7	38·1	5·3	53·0	2·4	0·0	15·2	+33·5	−14·8	+36·2	+36·7	+22·9
No control	16·6	42·0	40·3	23·7	30·6	0·0	48·5	10·5	0·0	14·7	+16·6	−6·5	+29·8	+23·7	+15·9
Mean (±0·86)	37·6	42·1	42·4	41·7	41·0	(±1·42) 29·7	47·9	39·1	16·4	33·3	(±1·79) +7·9	−5·8	+3·3	+25·3	+7·7

**Average room temperature*

(see *Figure 1*). *Table 1* shows that during the period April to October 1955, there was a significant decrease in viability with increasing moisture, the most serious reductions occurring with no moisture control at the lowest and highest temperatures. During the second year these effects were much more pronounced. There was a considerable loss of viability at temperatures of 20° and 60° F at the highest moisture percentage and also when there was no moisture control; at room temperature viability was not maintained for the full period except under the driest conditions (cf. *Figure 1*). The range of conditions for satisfactory storage is indicated in *Table 1*. Because of the changing moisture conditions, however, it is not possible to state precisely the degree of dryness necessary for satisfactory storage for any given period at any particular temperature. In particular, the final moisture content of the driest seed stored at room temperature suggests that the conditions may not need to be as extreme as 0·5 per cent moisture.

From this experiment it appears that seed may be stored for at least two years at high temperatures providing it is very dry or under cool conditions (45° F) irrespective of the moisture. These results are of practical interest since it would be necessary for a farmer to control only *one* of the factors and not both simultaneously.

Storage at 45° F would perhaps be safer since the moisture content is not critical but the viability is significantly higher at the higher temperature ($58{\cdot}5 - 48{\cdot}5 = 10{\cdot}0 \pm 4{\cdot}92$), the corresponding germination percentages being 73 and 56 per cent respectively. This effect of temperature may be observed throughout the range of conditions suitable for the maintenance of viability (*Table 1*). For this range of conditions the average of the changes shown in *Table 1* ($-5{\cdot}8 \pm 1{\cdot}13$) indicates the presence of a dormancy effect giving increased germination of 10 per cent after storage for two years.

SUMMARY

Seed of Mexican grass, *Ixophorus unisetus* (initial viability 85 per cent), was stored for two years under various conditions of temperature and moisture (20° to 80° F and 0·5 to 18·5 per cent moisture and also in an atmosphere of 70 to 100 per cent relative humidity). The viability was determined from samples on seven occasions during this time. In general, viability was lost under conditions of high moisture and especially at high temperatures whereas it was maintained at about 50 per cent under the drier and cooler conditions. Viability of the seed stored at 45° F but without moisture control was also maintained at this level whilst the driest seed stored at an average of 80° F gave over 70 per cent germination.

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Observations on the Root-knot Nematode in Papua–New Guinea

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In this paper an account is given of investigations on the root-knot nematode (*Meloidogyne* spp.) that were carried out at the Lowlands Agricultural Experiment Station, Keravat, up to January 1957. In addition to identifying the species that were present and recording some of the more important hosts, two main problems were considered. The first was to find whether the species of *Meloidogyne* that attacks *Leucaena glauca*, the tree commonly used as shade for cacao in Papua–New Guinea, is capable of attacking cacao itself. The second problem was to investigate the relative resistance of cover crops to attack by the nematode.

Of the crops that were investigated, cacao (*Theobroma cacao*) is the most important. Since 1946 large areas have been planted to cacao in the Gazelle Peninsula of New Britain and, to a lesser degree, in other parts of that island as well as on the mainland of New Guinea. The common practice is to establish *Leucaena glauca* as permanent shade-trees, augmented in the early stages by *Crotalaria anagyroides* or another quick-growing leguminous plant, and to plant cacao seed or seedlings only when the shade is adequate. Thus, the fact that *L. glauca* is a host of the root-knot nematode is of considerable importance.

Sweet potato (*Ipomoea batatas*), together with taro (*Colocasia esculenta*), is the main root-crop cultivated in the Territory and is a staple food of a large section of the native population. It is grown in village gardens from sea level to the Highlands and is also cultivated on a comparatively large scale as a cash crop by a few Europeans.

Peanuts (*Arachis hypogaea*) are grown by some European cultivators and are becoming increasingly important in native agriculture. Small areas of papaws (*Carica papaya*) are grown by Europeans and natives; the trees are nowhere cultivated on a plantation scale, but the fruit is an important item in the diet of the native population. The vegetables that were investigated are all grown, to varying degrees, in European and native gardens.

HOSTS AND IDENTIFICATION OF SPECIES

To January 1957, twenty hosts of *Meloidogyne* spp. had been recorded in Papua–New Guinea. Two species and one variety of the genus have been identified on the following hosts.

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M. incognita	Leguminosae	*Tephrosia candida*	Keravat near Rabaul, New Britain
	Solanaceae	*Lycopersicum esculentum*	Keravat
M. incognita var. *acrita*	Leguminosae	*Mimosa invisa*	Keravat
		Phaseolus mungo	Keravat
	Malvaceae	*Hibiscus esculentus*	Keravat
	Solanaceae	*Capsicum annuum*	Keravat
	Cucurbitaceae	*Cucurbita pepo*	Keravat
M. javanica	Caricaceae	*Carica papaya*	Fulleborn, New Britain
	Leguminosae	*Leucaena glauca*	Keravat
			Lower Markham Valley, near Lae
			Popondetta, Papua
		Phaseolus calcaratus	Keravat

Infestation of the following additional hosts has been observed, but the species of *Meloidogyne* has not been determined.

Chenopodiaceae
Beta vulgaris
Malvaceae
Hibiscus connabinus
H. rosa-sinensis
Solanaceae
Cyphomandra betacea
Solanum mammosum
S. melongena
Cucurbitaceae
Cucumis sativus
Umbelliferae
Daucus carota
Compositae
Dahlia variabilis
Zinnia elegans

Few native plants or weeds were examined for signs of attack by nematodes, and none was recorded as host of *Meloidogyne*. Soils from beneath several different plant communities (primary rain forest, secondary bush, and grassland) were screened for the presence of root-knot nematodes by planting surface-sterilized seed of the susceptible *Phaseolus calcaratus* and *P. mungo* in pots containing samples of these soils. The method failed to detect the presence of the root-knot nematode in any uncultivated soil, although they were recovered from cultivated soils. It was therefore concluded that the nematode population is insignificant in soils carrying primary forest, and in soils that have been out of cultivation for a sufficient period to revert to secondary bush.

INFECTION OF *Leucaena glauca* AND CACAO

Bessey (1911) recorded cacao as being susceptible to attack by *Heterodera radicicola* (*Meloidogyne* spp.). The leguminous tree, *Leucaena glauca*, which is used as shade for cacao, has been found to be a host of the root-knot nematode in the Gazelle Peninsula, the lower Markham Valley, and the Popondetta district. When severe infection occurs in the early stages the growth of *L. glauca* is retarded to a marked degree. Consequently, an experiment was carried out to find whether *M. javanica*, which infects *L. glauca*, was also capable of attacking the roots of cacao.

Knots taken from the roots of *L. glauca* were chopped finely and used to inoculate pots of steam-sterilized soil in which plants of *L. glauca* and cacao had been raised from seed; the plants were six weeks old at the time of inoculation.

Some inoculated plants of *L. glauca* were killed outright and the roots of the survivors were heavily galled. Both height and fresh weight were

markedly reduced in comparison with the controls, and the weight of knots removed from the roots was equal to about 50 per cent of the total weight of the entire plant in each case. Whereas the control plants produced a clean tap root with a mass of fibrous roots, the inoculated plants developed a restricted tap root bearing large knots within which mature female nematodes and egg masses were found; the fibrous roots were reduced in extent and numerous small galls were present upon them.

Examination of the inoculated cacao plants did not reveal the presence of knots or other signs of damage to their roots, and there was no significant difference in the growth of inoculated and un-inoculated plants.

INFECTION OF COVER CROPS

Root-knot nematode has been recorded on five species of *Leguminosae* that are used as cover crops. If *Phaseolus calcaratus* or *P. mungo* is planted three or four times in succession on the same soil, the plants are severely attacked by *Meloidogyne* and their growth is markedly affected. Accordingly, an experiment was undertaken to investigate the host range of the two species of *Meloidogyne* that had been recorded on these cover crops and, in particular, to find other cover crops that showed resistance to attack.

M. incognita var. *acrita* from *P. mungo* and *M. javanica* from *P. calcaratus* were raised on their respective hosts in pots of steam-sterilized soil. The knots thus obtained were macerated and the suspension used as the inoculum. Seedlings of five common cover crops were raised in pots of steam-sterilized soil and inoculated when they were 17 days old; 48 days after inoculation, the plants were removed from the soil, examined for infection and weighed. The results are presented in *Table 1.*

Table 1. Infection of cover crops by Meloidogyne *spp.*

Inoculated species	*Control* *Fresh wt* (4 plants)	M. javanica *Fresh wt*	M. javanica *Infection*	M. incognita *v.* acrita *Fresh wt*	M. incognita *v.* acrita *Infection*
Phaseolus calcaratus	126 g	72 g	++	82 g	++
P. mungo	35	10	+++	4	+++
Crotalaria anagyroides	22	28	—	21	—
Leucaena glauca	7	6	±	7	—
Pueraria phaseoloides	24	21	—	36	—

Knots were produced by the nematodes only upon *P. calcaratus* and *P. mungo*, and infection was reflected by a marked reduction in the weight of the inoculated plants in comparison with the corresponding controls. *P. mungo* was more severely affected by both species of nematode than was *P. calcaratus*, but both suffered greater damage from the species of *Meloidogyne* usually associated with them in the field. Some plants of *P. mungo* were killed outright by *M. incognita* var. *acrita.*

Growth of *L. glauca* was slow, possibly because of lack of effective nodulation which appears to be particularly important to this species. Although knots were not formed, there were signs that *M. javanica* had invaded the

root system. The other two species of cover crop did not show any damage to their roots, and growth of the inoculated plants was generally comparable to that of the un-inoculated controls.

DISCUSSION

With respect to the occurrence of the root-knot nematode the situation in Papua–New Guinea bears a fairly close resemblance to that described for Ghana by Edwards (1955, 1956), who concluded that the important species in that country is closely related to *M. incognita*. Other points of similarity exist in Edwards's record (1955) of the susceptibility of members of the families *Cucurbitaceae* and *Solanaceae*, and in the apparent immunity of peanuts from attack by the nematodes that have been investigated.

Some important differences also exist between the two countries. Thus, in Ghana, *Leucaena glauca* is apparently not a favoured host of *Meloidogyne* spp., but in Papau–New Guinea this plant may be attacked so severely by *M. javanica* as to prevent the establishment of satisfactory shade for cacao. By contrast, cacao has been recorded as a host of *Meloidogyne* in Ghana, but invasion of the roots of the Trinitario cacao grown in Papua–New Guinea has not been recorded and pot experiments indicate that it is immune from attack by *M. javanica*.

In his investigation of the reaction of a number of hosts to *Meloidogyne* spp., Sasser (1954) found that peanuts (var. Spanish, which is the common variety in Papua–New Guinea) were resistant to *M. incognita*, *M. incognita* var. *acrita* and *M. javanica*, but susceptible to two other species. It would appear, therefore, that the species to which peanuts are susceptible (*M. arenaria* and *M. hapla*) are not present in the districts in which these investigations were made.

Sasser recorded sweet potato as a host of *M. incognita* and *M. incognita* var. *acrita*, but in New Britain this plant has not been found to be susceptible to the root-knot nematode even in soils that contain high populations of *M. incognita*. The crop, which is extensively cultivated by the native population, exists as a number of distinct varieties so that selection for resistance may have been practised.

SUMMARY

The species of *Meloidogyne* that have been found to produce root knots on some plants in Papua–New Guinea are recorded and some aspects of their distribution are discussed.

Experiments on the susceptibility of certain crops are described. In pot tests cacao was not susceptible to attack by *M. javanica*, which is commonly found on the shade tree *Leucaena glauca* in the important cacao-growing districts of Papua–New Guinea.

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The Successful Breeding of Palpozenillia palpalis *(Ald.) (Diptera, Tachinidae) a Parasite of* Diatraea *spp.*

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Palpozenillia palpalis (Ald.) was first recorded by Myers in 1931 parasitizing the larvae of *Castnia licoides* Boisd. in the pseudostems of *Heliconia bihai* L. at Wanaima in the North West District of British Guiana. Since *Castnia* is an important pest of sugar-cane in British Guiana and Trinidad this discovery was of possible economic importance, and material was shipped to Trinidad where an attempt was made to breed the species in order that numbers might be liberated in the field against *Castnia*. This early work is summarized by Box (1955). In 1935 1 600 *Palpozenillia* puparia and larvae obtained from *Castnia* at Wanaima were shipped to Trinidad where 839 flies were obtained. Some of the puparia were parasitized by *Trichopria* sp. Unfortunately attempts at breeding this species in large numbers failed, and although 170 adults of the original stock were liberated (1936) no establishment occurred.

More recently Box (1955) has found this species in the sub-Andine region of Venezuela (April 1948) parasitizing a new species of *Diatraea*, *D. andina* Box, feeding on *Pennisetum peruvianum* Nees. In a small area the average parasitism was 50 per cent. On 15 March 1949 he found one specimen of *D. canella* Hmps.* in young sugar-cane at Guanava, Portuguesa State, parasitized by this species. Nine puparia were produced by this single larva.

In 1950 L. C. Scaramuzza obtained this species from *D. considerata* Heinr. in sugar-cane at Tepic, Narayit State, Mexico, and subsequently in Mexico it has been found commonly parasitizing *Zeadiatraea muellerella* (Dyar and Heinr.) in maize.

This parasite is thus widespread, and attacks a number of species of *Diatraea* (*sensu lato*) in addition to *Castnia licoides*. It occurs in a wide range of habitats, and appears to be very adaptable. Hence it might well prove to be of importance in the biological control of several different moth borers of sugar-cane, and possibly of maize, in a number of areas. It was therefore decided to investigate again the possibility of mass-breeding this parasite. The biology was incompletely known, but has been summarized by Box (1955).

At the outset of these investigations two sources of material were considered. In the first place it was thought possible that material might be

* Recently Box and Capps (1955) have subdivided the genus *Diatraea*, and *D. canella* Hmps. is now *Eodiatraea centrella* (Mosch.). However, *D. canella* is a familiar name for this particular cane borer, and to avoid confusion this name will be retained in this paper.

obtained through the cooperation of the Unión de Productores de Azúcar in Mexico, and secondly there was the possibility of visiting the area where Myers had obtained the original material in the hope of finding more. It was realized that there might well be a racial difference between specimens from these widely separated areas, particularly in view of the fact that they came from different species of host larvae, living in different host plants.

Purely on grounds of economy it was decided to commence investigations with material from Mexico. Some material was provided in 1951 through the courtesy of Ing. A. Gonzalez Gallardo of Mexico; this was collected from *Z. muellerella* in maize. Little material arrived in Trinidad alive owing to delays in air express service, and much of this was parasitized by *Trichopria*. Some mated females and fertile eggs were obtained and a few progeny reared. However, the full life cycle was not elucidated, and investigations had to be discontinued through lack of parasite material. In 1954 a further supply of material was obtained from Mexico and this arrived in a very much better condition. With this it was found possible to investigate the life cycle fully, and eventually to develop a successful mass-breeding technique.

BIOLOGY AND BREEDING TECHNIQUE

The biology of this species as known up to 1952 is given by Box (loc. cit.). Adults emerging from the puparia shipped by Myers to Trinidad in 1935 were placed for mating in large cages, 1·85 m high and 1 m in diameter, covered with dark green cloth, as it was found that in cages covered with white cloth no mating occurred. In these green cages mating occurred only in the early morning. Flies were fed on sugar-water or cane-juice and the interior of the cages was kept very humid. Pieces of cane containing *Diatraea* or *Castnia* larvae were placed in the cages. From the progeny obtained by exposing host larvae in this way it was calculated that the preoviposition period was from 10 to 14 days. Vesey-Fitzgerald found that in *Castnia* the first larval stage lasted for 20 days and that from oviposition to adult emergence took 72 days. With *D. canella* as host Box, working in Venezuela and using a similar technique, obtained 2 adult progeny 25 days after the host larvae had been exposed to ovipositing female *Palpozenillia*; of this the pupal period lasted 12 days. In Trinidad the pupal period was recorded as 20 days, and with the material reared in Venezuela from *D. andina* it lasted 21 days.

Dissection of adult female *Palpozenillia* showed them to contain 600 to 800 eggs in the ovisac.

Many puparia were obtained in a number of instances from a single host. Myers obtained up to 40 from individual field-collected *Castnia* larvae, and as many as 52 in the laboratory. In Venezuela Box obtained 9 puparia from a field-collected *D. canella* larva and 13 from *D. andina*. In Mexico he obtained 15 from a larva of *D. considerata*.

There was therefore a gap in the knowledge of the life history of this parasite; the method of hatching of the egg and means of entry of the larva into the host, and the course of larval development were unknown.

Puparia received from Mexico in August 1954 were placed in damp

moss in tins in cages 14 in. × 10 in. × 10 in. with a wooden frame, white cheesecloth sides and back and a sliding plastic front. The moss was kept damp throughout the emergence period.

On emergence male and female flies were kept in separate cages of similar construction and supplied with food in the form of split raisins and cotton wool pads soaked in dilute sugar-water. This food was changed each day to avoid fermentation. Water was provided in the form of soaking cotton wool in Petri dishes, and the cages were kept very humid by spraying periodically with water.

In the early morning a few females were placed in the cage containing males. When only a few males were in the cage mating was not rapid, but when there were fifty or more males in the cage mating occurred readily very soon after the females were introduced into the cage a few at a time. It was not found necessary to have large cages covered with green rather than white cloth. Mating occurred usually before midday but not especially frequently in the early morning. If mating did not occur readily the cage was moved from shade to sunlight and back at frequent intervals. These changes appeared to activate the males.

Coupled pairs were carefully removed from the cage in glass vials and left undisturbed until they had separated. Males were returned to the mating cage and the females placed individually in small cages ($4\frac{1}{2}$ in. × $4\frac{1}{2}$ in. × 3 in.) of similar design to the larger ones, provided with food and water as before and kept very humid. In addition sprigs of railway daisy (*Bidens pilosa* L.) were provided to give possible additional food for the flies.

Into each of these small cages was placed a piece of sugar-cane containing a three-quarter to full-grown larva of *D. canella*, the cane being cut so that the piece bore the external opening of the larval tunnel. About five days after mating females began to show an interest in these pieces of cane, particularly the external holes which are usually surrounded with a narrow rim of brown decaying cane and larval frass. These flies were then kept under close observation. Females ran over the cane ' examining ' it and would often ' hop ' for some time around the tunnel entrance, extending and retracting the telescopic ovipositor at the tip of the abdomen, bending it ventrally and forwards. The tip of the abdomen was in this way thrust some distance down the tunnel. After this had continued for some time the females ceased activity and became disinterested in the cane, and had apparently laid eggs. The pieces of cane were then either set aside for possible development of the parasites or were examined for eggs with a binocular microscope.

Fresh pieces of cane containing *D. canella* larvae were substituted in the cages for the pieces removed. A number of cages were set up in this way and considerable time spent in keeping them under close observation. From the *D. canella* larvae in pieces of cane exposed in this way it was possible to keep a breeding stock of *Palpozenillia* while details of the biology and a mass breeding technique were worked out.

Examination of the ' attacked ' pieces of cane eventually showed that the minute (approximately 0·02 mm × 0·1 mm) eggs were laid, sometimes several together, at or near the entrance of the tunnel made by the host larva.

Usually they were a very short distance down the tunnel from the surface of the cane, laid on the frass or decaying tissue. The eggs are ovoid, convex dorsally and flat or slightly concave ventrally where the egg membranes are more transparent and thinner than dorsally where the egg is opaque white.

These eggs contain minute fully formed larvae with conspicuous mouth-hooks. If an egg is placed on a slide and observed under a microscope, and then touched with a needle point the contained larva quickly contracts, drawing its anterior end well away from the egg chorion. If such eggs are kept wet the larvae within them remain alive for up to five days but do not emerge from the egg.

Mated females were dissected when about nine days old, after they had already been ovipositing on cane pieces. The ovisacs were removed and the eggs therein spread out on a microscope slide in a film of water. If dissected four days after mating females were found to have only a few of the eggs in the lowest part of the ovisac containing developed larvae; with increasing age of mated females prior to dissection, up to about ten days, more and more of the eggs were found to be mature. It was also found that if the eggs from a mated female were left on a wet slide and this was kept in a relative humidity of 100 per cent in a Petri dish, more eggs gradually became mature over a period of several days. Up to 900 eggs were counted in the ovisacs of individual females.

As it was obvious that the mature eggs contained fully developed and active larvae several methods of inducing hatching were tried. Numbers of mature eggs were placed on slides and examined under the microscope when covered with cane juice of various dilutions, extract of rotting cane, very dilute hydrochloric acid and caustic potash (see WISHART, 1956), haemolymph and intestinal fluids from *D. canella*. In none of these did hatching of the eggs occur.

Mature eggs were placed in the furrows in the skin of *D. canella*, since from the flattened shape of the egg it seemed possible that, in spite of the mode of oviposition of the females in cages, application of the eggs to the skin of the host might be the normal method of parasitism. This was not successful.

Eggs on a needle point were ' fed ' to *D. canella* larvae but the eggs became stuck with saliva at the sides of the mandibles. This method, too, was unsuccessful.

In order to feed the eggs to the host larva more successfully small pieces of cane were cut so as to fit exactly into (1·5 in. long) lengths of narrow (approximately $\frac{1}{8}$ in. diameter) glass tubing of approximately the same diameter internally as that of a fully grown *D. canella* larva. A $\frac{1}{4}$ in. long plug of fresh hard sugar-cane was placed at one end so that the surface of the cane was flush with the edge of the glass tube. Four or five *Palpozenillia* eggs were placed on this surface by means of a fine needle and the pieces of glass tube were then carefully placed in a glass vial so that the exposed sugar cane surface was not touching the bottom of the vial. Almost full-grown *D. canella* larvae which had been starved for 24 hours were placed individually in these vials, which were then tightly plugged with cotton wool. Most larvae soon began feeding on the surface of the cane and

ingested *Palpozenillia* eggs along with the cane. These larvae were removed and placed with larger pieces of fresh cane in plugged glass vials and left for further development. A number of host larvae did not feed readily. These were removed from the vials containing *Palpozenillia* eggs and replaced with others.

Later a modification of this method was introduced. The *Palpozenilla* eggs on small pieces of cane in glass tubing were prepared as before but the cane plug was then pushed down to the far end of the tube, the *Palpozenillia* eggs now therefore being on the side of the cane plug facing the inside of the tube. A *D. canella* larva was then put into the tube, with its head facing the cane plug and the tube was closed behind the larva with a cotton wool plug. The glass tube was put into a plugged glass vial as before. Thus to escape from the small tube the host larva had to eat its way through the sugar cane plug and ingest *Palpozenillia* eggs.

Dissection showed that within 24 hours of feeding, the *Palpozenillia* eggs that had been ingested (naturally not all the eggs put on the cane pieces were actually ingested) had hatched in the anterior part of the gut. Some first stage larvae were found here free and active in the intestinal fluid, while others had bored through the intestinal wall and were free in the haemolymph. These parasite larvae then enter lobes of the fat body where they begin their development. They grow actually within the fat body and not free in the haemolymph. The rate of development varies considerably, presumably depending on the physiological state of the host larva and particularly on that of the fat body.

The three larval instars are passed in the fat body in this way. During the third instar the larvae feed rapidly and consume almost the entire body content of the host. They then break out of the host larval skin and form their puparia, which may also be found in the empty host skin. Under natural conditions puparia are formed in the host tunnels.

With *D. canella* as host it was found that the minimum time from ingestion of parasite eggs to puparium formation was nine days. However, in vials in the laboratory *D. canella* had a tendency to enter a form of diapause, which is very difficult to break artificially, and the development of the larval parasite may be halted for a considerable time resulting in a lengthy though varying developmental time. This halt occurs in the first larval instar of the parasite whilst it is in the fat body. Efforts to break the host diapause resulted in considerable mortality.

D. canella was not therefore a very suitable host for mass-breeding of the parasite and other species were tried, *D. saccharalis* F., *D. impersonatella* Wlk. from sugar-cane as well as *Castnia licoides*, the first recorded host of *Palpozenillia*. In addition *Zeadiatraea lineolata* Wlk. (see Box, 1955) from maize was used.

It was found that *Palpozenillia* could be bred on the two additional *Diatraea* species, as well as on *Z. lineolata*, but no success was obtained with *Castnia*. This last is somewhat surprising since *Castnia* was the first recorded host of this parasite. However, it must be remembered that the original material obtained by Myers from *Castnia* was from British Guiana and that the material used in these investigations was from stock from Mexico. It is highly probable that there are a number of races of this species with

different host preferences and tolerances, as well as differences in the optimum environmental conditions for any particular strain.

With the present breeding work the most suitable host was found to be *Z. lineolata* which is a pest of maize and is in the same group as *Z. muellerella*, a maize pest in Mexico from which the original stock of *Palpozenillia* was obtained. This may indicate that there is here a race of *Palpozenillia* particularly adapted to the ' maize *Diatraea*s'.

Since a single host larva is capable of supporting to maturity a number of parasite larvae an experiment was set up to determine the effect of exposing different numbers of eggs of *Palpozenillia* to individual host larvae (*Z. lineolata*). Although 1 166 host larvae were individually fed pieces of cane bearing from 1 to 8 *Palpozenillia* eggs the results were disappointing owing to high larval mortality and tendency to diapause, and no optimum number of eggs per host larva could be obtained; exposing two per piece of cane gave as good a ' yield ' as any and minimum waste of eggs.

With this technique and using both *D. canella* and *Z. lineolata* as hosts a large number of *Palpozenillia* were bred for field release in British Guiana, Trinidad, St Lucia and St Vincent, B.W.I. Both adults and puparia were shipped out of Trinidad to the other areas where liberations were made in cane fields infested with *D. canella* larvae (and *Castnia* in British Guiana). In Trinidad releases of definitely mated females as well as mass releases of flies were made in sugar-cane infested with *D. canella* and *Castnia*, in stands of *Paspalum virgatum* heavily infested with *D. canella* larvae, and in maize infested with *Z. lineolata*. In one instance parasitized *D. canella* larvae were released in a field of *Paspalum virgatum* L. at Piarco, Trinidad.

The total amounts of material released in Trinidad or shipped to the other areas were:

	No. of shipments	Total *Palpozenillia*
Trinidad	11	4 768
British Guiana	9	5 200
St Lucia	4	1 000
St Vincent	2	500
Total	26	11 468

No reports of establishment have been received from either St Lucia or St Vincent, and it is likely that no extensive investigations have been made.

In British Guiana releases were made by J. Bates, entomologist of Bookers' Sugar Estates Ltd, and a careful check was made in the field following liberations. In one instance only out of a very large number of *D. canella* collected and examined was a single recovery made of *Palpozenillia*.

In Trinidad extensive recovery collections were made, particularly at Usine Ste Madeleine in sugar-cane (and to a certain extent in nearby maize), in maize at the Imperial College of Tropical Agriculture, and in *Paspalum* at Piarco. Four puparia were recovered from *D. canella* (one each from four larvae) in sugar-cane at Usine Ste Madeleine, and one from *Z. lineolata* in maize growing near the cane. Twelve puparia were recovered from *Z. lineolata* in collections made in small patches of heavily attacked maize at the Imperial College, and none from *D. canella* in *Paspalum* at Piarco.

It was felt that in both these areas this material had been given adequate trial, but that in all probability it was a strain of the species adapted to the *Zeadiatraea* group of moth borers [and therefore might be of value against *Z. grandiosella* (Dyar)]. It is possible that material from other parts of the range of *Palpozenillia* and from other hosts might prove more successful against *D. canella* and *Castnia.* Now that a technique for breeding this species has been developed it is hoped that material of this parasite from different hosts may be obtainable and experiments carried out with it. In an attempt to do this J. Bates and J. Proctor, entomologist of the British Guiana Department of Agriculture, made an expedition to the same area where Myers originally found *Palpozenillia.* Although a large number of *Castnia* larvae were collected and examined no *Palpozenillia* was found.

SUMMARY

The Tachinid parasite *Palpozenillia palpalis* (Ald.) was discovered in 1931 as a parasite of *Castnia licoides* Boisd. and subsequently as a parasite of several species of *Diatraea* in Venezuela and Mexico. It had obviously possible economic importance as a parasite of several sugar-cane borers and several unsuccessful attempts were made in the past to breed this species in numbers. This is an account of a successful breeding method and attempts, which were apparently unsuccessful, to establish the parasite in Trinidad, British Guiana, St Lucia and St Vincent, B.W.I. The probability is discussed that there are several biologically distinct races of this species, with different potentialities with regard to the control of *Diatraea* spp. and *Castnia.*

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The Selection of Oils for Spraying against Leaf Spot Disease of Banana

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The spectacular results obtained by Cuillé and Guyot (1953, 1954, 1955) and others in the French Antilles have resulted in a widespread demand for oils suitable for spraying on to bananas to control Leaf Spot Disease, *Mycosphaerella musicola* Leach.

Opinion is still divided as to what constitutes a suitable oil but nevertheless certain facts have been established. All oils used for spraying are toxic to both host and pathogen to a greater or lesser degree, either because of the physical or chemical properties or both. The cost of an oil is largely determined by the degree of refinement and usually spray oils have an unsulphonated residue of between 80 and 90 per cent. Generally speaking oils are selected for spraying on a basis of unsulphonated residue, viscosity and cost.

It is impossible for individual banana growers to test oils for their suitability, but advice on such matters is frequently sought from local research and advisory establishments. Sometimes oils are tested by spraying young maize or bean plants and observing phytotoxic symptoms, but this method is only satisfactory if conditions of light, humidity, temperature and growing medium are kept constant. The difficulties of having an experiment of sufficient accuracy and of a duration long enough to ascertain all undesirable effects are not easily overcome. The limitation of this type of experiment is that it relies solely on observable symptoms. There may well be hidden effects such as a longer maturing period and a reduction of yield.

In the past mycologists, to avoid frequent subculturing, flooded fungal colonies growing on agar with liquid paraffin. This is a pure saturated oil and has the effect of retarding growth and is not fungicidal.

It was thought that this principle could be applied using spray oils and measuring the effects quantitatively. If a fungal colony was flooded with a spray oil, the effect could then be compared with a similar colony growing under liquid paraffin. Because a spray oil is not fully saturated the effect on fungal growth would be partly physical and partly chemical, and would consequently exert a greater effect than the purer liquid paraffin. If this premise is accepted to explain the greater retardation of the growth of a fungus then it may be accepted in part as a measure of toxicity to a higher plant. As a result, by growing fungi under spray oils and measuring the growth rates comparatively, oils may be screened for toxicity quickly and accurately in the laboratory.

Method of Assessment

In order that the conditions of assay could be readily repeated, equal quantities of both media and oil and, so far as possible, inoculum were

used. Plates of Sabouraud's Agar were poured and inoculated with mycelium of *Fusarium oxysporum f. cubense* (E. F. Smith) Snyder and Hansen and incubated for two hours. (A *Fusarium* species was used as it was a readily obtainable fungus.) After two hours 15 ml of spray oil or liquid paraffin was poured on the plates. The oils were sterilized to avoid any contamination. The plates were then incubated for 72 hours. The treatments were fully replicated and randomized within the incubator to permit statistical analysis of the results. After the incubation period the growth of the colonies was measured by taking the mean of two diameters at right angles to one another. The retardation of growth was expressed following the method of Topps and Wain (1957) where the percentage retardation of the fungal growth is given by the formula

$$R = (d_c - d_t)\ 100/d_c$$

where d_c = diameter of control colony, d_t = diameter of colony under spray oil, and R = percentage retardation of growth.

Five spray oils recommended by four large oil companies for Leaf Spot Disease control were obtained. They all had similar unsulphonated residues and viscosities, and were paraffin-based (see *Table 1*).

Table 1. Unsulphonated residues and viscosities

Spray oil	*Unsulphonated residue**	*Viscosity* 100°F *SUS*†
A	86	145
B	85	78
C	80	108
D	84	108
E	84	99

* Makers' specifications. † Saybolt Universal Standard.

In each experiment the seven treatments (no oil, liquid paraffin and five oils) were replicated four times. In order to check reproducibility the experiment was repeated four times. The results of these four experiments are given in *Table 2*, where the average diameters of the fungal colonies are expressed in millimetres multiplied by ten.

Table 2. Mean diameters of fungal colonies

Treatment		*Experiment number* 1	2	3	4	*Total*
Control		318	288	293	299	1 198
Liquid paraffin		264	255	311	268	1 098
Oil	*A*	210	190	222	205	827
	B	274	240	300	259	1 073
	C	200	195	232	215	842
	D	218	210	252	224	904
	E	244	239	261	245	989
Total		1 728	1 617	1 871	1 715	6 931

The significant difference, calculated on the pooled residual error at the 0·1 per cent level, is 124.

The results obtained from the application of Wain's formula are given in *Table 3*.

Table 3. Percentage retardation of growth

Treatment		*Over control*	*Over liquid paraffin*
Liquid paraffin		8·3	—
Oil	*A*	31·0	24·7
	B	10·4	2·3
	C	29·7	23·3
	D	24·5	17·7
	E	17·4	9·9

DISCUSSION AND CONCLUSIONS

Several points stand out as a result of these experiments. In no case over the duration of the experiment did a culture die and this is strong evidence that spray oils act as fungistats like liquid paraffin and not as fungicides. It has been possible to repeat these results with no difficulty although minor differences in culture technique, temperature gradients in the incubator etc., led to levels of significant difference being reached between incubator shelves and experiments, but these differences are of minor importance when compared with the treatment effects.

The growth of a fungus under spray oils of similar specifications varied considerably. Of the five oils all were recommended for use on bananas. It would seem, therefore, that the different growth rates might be due to the different chemical natures of the unsaturated fractions.

It would seem that if there is a positive correlation between the phytotoxicity to a plant and an increasing retardation of growth of fungus then it is possible to screen oils in the laboratory for their suitability for spraying.

It is thought that oils which retard fungal growth by less than ten per cent when compared with growth under liquid paraffin should be used in preference to other oils. Comparison with liquid paraffin is preferred to comparison with no oil because the conditions seem more comparable.

If the physical effect of an oil can reduce hyphal growth of a *Fusarium* species by eight per cent, it would seem a reasonable assumption that the effect of the same oil on a germinating *M. musicola* spore would be at least as great. If this is in fact a true hypothesis the chemical effects (and therefore phytotoxic effects) of a spray oil are undesirable. The suitability of a spray oil must therefore be selected by equating purity of refinement with cost.

It may be that the perfect oil for spraying bananas economically does not exist. It is unfortunate that the cost of an oil increases with the refinement because it seems that an oil with a very low unsulphonated residue would provide the best answer. The ultimate choice of a spray oil must depend upon the magnitude of the long-term debilitating effects on the plant and consequently reduced fruit weight. But this has to be determined by long term experiments to ascertain how much the fruit weight can be reduced while maintaining profitable production. The desirable margin of profit varies from one part of the world to another and consequently so might the choice of a suitable oil.

It is not suggested that this method of assessment is entirely satisfactory; for instance it does not take into account the absorption of ultra-violet light by spray oils, which may well alter the photosynthetic capacity of a green plant. But if used in conjunction with other tests it provides a quick and easy method of determining in part the suitability of an oil for spraying.

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Book Reviews

THE GRASSES OF BARBADOS

J. A. Allan. *Colonial Research Publications No. 23.* Her Majesty's Stationery Office: London, 1957. *vi* + 114 *pp.* (illus.) 7*s* 6*d*

The publication of a book of factual reference is justifiable on two main grounds: either the presentation of new, or hitherto unpublished, information or the revision, correction and presentation in a more lucid and available form, of older material. Mr Allan's work conforms with the latter as he mentions in his preface: ' The description of the subfamilies, tribes and genera, and keys to the same have been selected from Hitchcock's *Manual of the Grasses of the West Indies* and adapted to include only the local species '. Hitchcock's invaluable manual has been out of print for several years and this Barbados annotation therefore serves a most useful, if geographically limited, purpose. We are, furthermore, assured by Dr Salisbury in an introduction, that the nomenclature used in Hitchcock's 1936 publication has been revised ' in conformity with present conceptions ' by no less an authority than Mr C. H. Hubbard of Kew.

In several instances, however, particularly in *Andropogon*, older nomenclature is retained in the keys and index whilst current synonyms are included in the text.

The arrangement of subject matter commences in the usual sequence for a work of this nature, i.e. with descriptions and keys of the subfamilies, tribes, genera and species.

The next section affords perhaps most interest and that is a key to the 67 uncultivated species based on green or vegetative characters. Such a key is invaluable for any studies on grazed swards but is presumably practical only where speciation is limited; in Barbados there are but six Panicums and seven Paspalums whereas Trinidad for example records 25 and 23 species respectively. In this key the main subdivision is made according to whether or not the plants are ' grass-like ' or ' not typically grass-like ' based on leaf width or woodiness of culm. This is likely to be misleading for *Panicum pilosum* and *Oplismenus hirtella* which are both included in the latter division. No attempt is made to specify *Eragrostis*.

Following this there is a tabulated index giving common names, economic uses, distribution and collection habitats. A comprehensive glossary of agrostological terms is next provided and will prove most useful for the tiro.

The booklet concludes with 56 expanded line drawings in alphabetical order of the majority of the grasses mentioned textually (the index thus coming rather obscurely in the middle). An unusual, but not incongruous, feature in a graminaceous flora is the inclusion of all cultivated species.

The publication is very reasonably priced and lightly but robustly bound.

It should find particular use at secondary school level in Barbados and serve as a model for similar localized flora elsewhere.

One wonders what transpired during the fourteen years between the date of the preface and that of publication.—R.H.F.

CITRUS FRUITS

H. Harold Hume. Macmillan: New York and London, 1957. *xxi* + 444 *pp.* (illus.) *U.S.* $10.50 or 73*s* 6*d*

The author of this book has had nearly 60 years experience in the growing of citrus and is a world expert on the crop. He has written two books previously on its culture, in 1904 and in 1926. This book has been written, during the author's lifetime, in order to revise the previous volumes thoroughly and incorporate up-to-date information. The format is essentially the same.

It is perhaps important to note that the U.S.A. contributes about 45 per cent of the world's current production of both oranges and lemons and about 90 per cent of the grapefruit. The importance of the crop there has led in recent times—prompted particularly by rising costs, principally those of labour—to intensive scientific research. This has resulted in the reduction of production costs, increased yields, improved appearance and quality of fruit, and broadened markets.

This book deals with citrus in all its aspects and includes a description of varieties and stocks available, their propagation, cultivation, techniques applied, the use of fertilizers, irrigation, pest and disease control and the harvesting and marketing of fruit. The subject matter deals almost exclusively with the cultivation of the crop in the U.S.A., notably in Florida and California.

Whilst the information contained in this notable general treatise on citrus is particularly applicable to conditions found in the U.S.A., a large proportion of it is of considerable value to students, research workers and commercial growers in the tropics. One of the principal lessons to be learnt from the book is the importance of treating the cultivation of citrus in an intensive manner, and thereby obtaining high yields of good quality fruit at an economic level. Far too often in the tropics techniques of cultivation leave much to be desired and this leads to poor, uneconomic yields of fruit. —J.S.C.

JOURNAL of the RUBBER RESEARCH INSTITUTE of MALAYA

Vol. 15, Part 1

Rubber Research Institute of Malaya: Kuala Lumpur, Federation of Malaya, 1957. 52 *pp. Straits* $3

This issue of the well established *Journal* of the Rubber Research Institute of Malaya appears in a new format with a brighter cover and rather larger pages and announces several relatively minor innovations which are to be introduced from now on. In addition to reports of experimental work and research carried out at the Institute it is intended to include an occasional paper devoted to a review of work done elsewhere in order to provide a fuller background to the specialized studies on rubber. In the current issue the paper by G. A. Watson on 'Cover plants in rubber cultivation' reflects this aim as it provides a general review of major factors relating to the use of leguminous cover crops and includes a long list of references. It is also intended that published research papers shall in future be rendered more succinct by the omission of detailed tables of experimental data. Such

detailed data will, however, be deposited in the R.R.I. Research Archives in the Library of the Institute from whence copies will be provided whenever the need arises.—C.C.W.

A SYMPOSIUM ON THE OPERATING COST OF MACHINERY IN TROPICAL AGRICULTURE

Edited by J. E. Mayne. [Colonial Advisory Council of Agriculture, Animal Health and Forestry, *Publication No. 4.*] Her Majesty's Stationery Office: London, 1957. *vii* + 59 *pp.* 7*s* 6*d*

This small symposium contains papers upon the cost of operating tractors and agricultural machinery on government and quasi-government agricultural stations in Nigeria and on a mechanized rice farm in Tanganyika, and a paper on the economics of the contract ploughing services provided by the government of Uganda. There is also a paper on the estimated costs of proposed mechanized paddy farms in the Federation of Malaya and two further papers on forward budgeting and methods of costing machinery respectively.

Limited information has, hitherto, been available on the economics of operating machinery in the tropics, and though the data presented in the first four papers of this booklet provide a reasonable means by which to measure the comparative efficiency of existing enterprises, this also serves to emphasize the very wide variation of costs that may appertain in different localities and conditions. The manner in which such data can be used to predict the probable cost of mechanized operations in enterprises still in the course of planning is clearly shown in the fourth paper.

The data quoted also show that tractor costs are generally higher in the tropics than in temperate regions, that this is largely due to high maintenance costs and rapid depreciation and that, as a result, many mechanized projects are of doubtful economy. Unfortunately, no overall conclusions have been drawn from the very interesting facts presented in these papers and, although it conforms with the policy stated at the end of the introduction, this detracts considerably from the value of the work as a whole.

Papers on ' The use of records and accounts in the development of systems of mechanized farming in the tropics ' and ' Costing machinery operations ' provide detailed information on methods of costing and recording, but the records used for purposes of illustration appear to be rather complex and would be difficult to maintain in the circumstances likely to prevail in many parts of the tropics.

This is a very useful publication and the contributing authors, W. T. Newlyn, N. R. Fuggles-Couchman, H. E. Hubbard, R. K. Kerkham, D. Innes, A. J. Armitage, D. W. M. Haynes and J. R. Raeburn and the Editor, J. E. Mayne, are to be complimented on the results of their combined efforts.—P.H.R.

PLANT PROPAGATION

J. P. Mahlstede and E. S. Haber. Wiley : New York; Chapman and Hall: London, 1957. *x*+413 *pp.* (illus.) *U.S.* $7.50 or 60*s*

This book, written for the experienced nurseryman and the student of plant propagation, would be a useful addition to the bookshelves of both.

Plant propagation, the increase of plant numbers sexually and asexually, is a broad subject to attempt to cover in one volume; however, the authors have managed to condense into the book a wealth of information covering much of the field without detracting from its specific usefulness to the man who requires a book on the practice of propagation. A single volume embracing subjects from mushrooms to the Malling rootstocks must perforce suffer in detail but where obvious gaps have been left in the text, careful use of selected references has been made at the end of each chapter.

One of the chief values of the book is the straightforward account of the basic physiological requirements for the successful propagation of plant species combined with a simple, clearly illustrated account of basic plant anatomy, sufficient for the needs of the propagator. Lack of this fundamental knowledge frequently leads to disappointing failures when new methods of propagation are being attempted. Many books of a comparable type either treat these aspects too superficially or attempt anatomical descriptions which are comprehensible only to advanced students of botany.

The text is divided into five parts, the first of which presents the basic concepts and principles of propagation. Part II deals solely with propagation by seeds including an account of physical and chemical treatments which may be used to improve germination and to prevent infection in the soil. The remaining three parts deal comprehensively with the major methods of vegetative propagation, including the construction of propagating frames, humidifiers, etc. The modern techniques using mist propagation and the use of polyethylene sheeting are adequately considered. The commercial practice of propagation of approximately 250 common trees and herbaceous plants has been included as a separate appendix.—R.N.

SMALL-FARM FINANCING IN JAMAICA

C. S. McMorris. Institute of Social and Economic Research, University College of the West Indies: Jamaica, 1957. *xiv* + 128 *pp.* (Originally published as a supplement to *Social and Economic Studies*, Vol. 6, No. 3, 1957.)

The material for this study was collected in the course of a wider survey which investigated in considerable detail the operation of certain selected small farms. As with most detailed economic surveys, the study is based on case histories rather than a controlled sample and in order to contrast cases, farms were divided into nine types-of-farm areas. The analysis of finance has been reported separately from the main survey because the author suggests it is too detailed and unwieldy to be included in the main report. This may well be so but the present study suffers somewhat from the lack of an overall financial background; for instance, contrasts are drawn between differences, say, in total indebtedness by types, but this cannot be related to total and seasonal income, expenditure or total capital invested in each of the types.

Nevertheless, the study proves to be a workmanlike analysis of credit, sources and application, the working of different credit agencies, etc. It reveals some most important and fundamental facts about small farming which in theory are often overlooked or ignored. A large amount of the finance of these farms is obtained from savings, inheritance or gifts; farmers

are most reluctant to offer their freehold land as collateral for loans. The overall indebtedness averages only £5 per farm or 16*s* per acre. These facts rather indicate that one of the main problems of financing small farms in Jamaica (and no doubt in other West Indian islands) is not so much providing the funds and agencies to administer them; it is more in demonstrating the overall profitability of small farms that employ more capital really productively and so convincing farmers that the risks and responsibilities of more capital lead to more than commensurate rewards.—A.L.J.

CONTROL OF THE PLANT ENVIRONMENT

Proceedings of the University of Nottingham Fourth Easter School in Agricultural Science, 1957

Edited by J. P. Hudson. Butterworths Scientific Publications: London, 1957. *xvi* + 240 *pp.* (illus.) 42*s*

This book is essentially the edited proceedings of the University of Nottingham Fourth Easter School in Agricultural Science, held in April 1957 to discuss the ' Control of environment in crop experimentation '.

A number of problems basic to agriculture and horticulture may be studied with a plant in a controlled environment, that is a predetermined climate may be imposed upon a plant species and its reaction studied. Photoperiodism, thermoperiodicity, humidity, light intensity, soil structure, etc. variously affect the reproduction, morphology and anatomy of plants but owing to the complex interaction of the climatic and edaphic factors, the analysis of any one response to any one factor is difficult. One method of approach is to fix at least some of the contributory climatic factors and vary that factor which may be of immediate interest. For example, at least one factor which may determine the ' flushing ' cycle of cacao, is temperature. It should not be difficult therefore to grow small cacao plants under a predetermined light intensity and humidity and to vary the temperature. In short, a problem on which only tentative conclusions could be drawn from an analysis of field experiments might be readily answered by use of a controlled environment room.

However, the construction of the growth rooms to provide the controlled environment is another problem and it is of great benefit that the papers from the conference, written by specialists in this field, have become available to other interested workers. It is noteworthy that over 70 university departments and research establishments in Britain are equipped for this type of work and the range of equipment in use and its relative value is admirably covered in this book. As with other conferences, discussion after the presentation of the papers is an integral part of the proceedings and edited accounts of the ensuing discussions follow each paper.

The proceedings are presented in four major parts. Part I, in which seven papers are presented, deals with the effects of the environment on plants. Part II, ' Control of environmental factors for plant experimental work ', consists of three papers and might be appropriately considered with Part III, ' Installations for the control of plant environment '. The two parts cover

descriptions and management of varying types of controlled environment chambers in common use today, ranging from the 'Phytotron' at the Earhart Laboratory in California to the modest growth cabinets where some degree of temperature control is all that is demanded. Part IV is of limited value in that it is essentially a review of the demonstrations displayed at the School. The descriptions of the exhibits are, however, adequate to enable the interested reader to form some idea of the demonstrations on view.

A useful index of plants mentioned in the text is included at the end of the book.—R.N.

A CRITICAL REVIEW OF THE TECHNIQUES FOR TESTING INSECTICIDES

J. R. Busvine. Commonwealth Institute of Entomology: London, 1957. *ix* + 208 *pp.* (illus.) 30*s*

During the past ten years many new synthetic insecticides have been produced; during the same time over thirty species of insect pests have, in different parts of the world, developed strains resistant to several of them that had initially been highly effective. The necessity for accurate and standardized laboratory testing of insecticides is therefore apparent.

This review, published in the autumn of 1957, covers the literature on the subject up to the spring of the same year. The author and publishers are therefore to be congratulated on its prompt appearance—too often such reviews are largely out of date before publication. Some idea of the magnitude of the task involved can be gathered from the fact that 551 references were consulted.

The subjects covered include the handling and standardization of test insects, and laboratory techniques for testing fumigants and repellents as well as stomach and contact poisons and systemics. *Ad hoc* methods of conducting insecticide trials in the field are not dealt with.

One small criticism. The author states that in the course of reviewing the various techniques it is only natural that he has formed certain opinions about their relative merits. Nevertheless he has presented the facts 'in such a way that the reader can form his own judgement of them'. The experienced worker can no doubt do so, but the beginner might have profited by a more critical review. If the author with his great experience had given more advice on what he considers to be the best techniques it would have been a step towards standardization, which, as he stresses, is badly needed.—T.W.K.

MAGNESIUM: THE FIFTH MAJOR PLANT NUTRIENT

A. Jacob. Staples Press: London, 1958. *xii* + 159 *pp.* (illus.) 40*s*

The author states his view that for too long a time has the NPK mixture been accepted as the only fertilizer amendment necessary to ensure high crop yields and that, although calcium has also been accepted as a major nutrient, far too little attention has been paid to the role of magnesium. It is certainly true that too many reported analyses, both of soils and plants, stop at the NPK level, and that only in recent years are columns for calcium and magnesium contents appearing in tables of analyses.

After a short account of the chemistry of magnesium, the book deals with the magnesium levels found in plants and the symptoms associated with magnesium deficiency are described for a wide range of crop plants. The information is of varying value—under chicory, for example, the only information is: magnesium deficiency led to a considerable decrease in growth both of roots and leaves. For the cantaloupe, it was found that severe magnesium deficiency symptoms were shown in the leaves if it was grown in nutrient solutions with an inadequate supply of magnesium. Such statements are of no more value than a mention of the reference. For the more important crop plants, however, the information is better presented and the deficiency symptoms of a number of crops are illustrated by a series of coloured and black and white photographs.

Later chapters deal with the functions of magnesium in the plant and animal, ionic antagonisms and soil investigations for magnesium. In this last, methods of analysis are discussed insufficiently critically. The difficulties associated with the Titan yellow methods are hardly considered and there is no mention of flame photometry. The lack of a quick and reliable method for magnesium analysis is one factor responsible for the neglect of this nutrient.

The final chapters consider fertilizer experiments with magnesium and the sources of magnesium fertilizers. The former tends to be a series of extracts from original papers and makes heavy reading—on 13 farms in Virginia the potato crop was increased by magnesium on the average by 6·8 bushels per acre. In Rhode Island on acid soils the addition of magnesium increased the crop very much; at least 25 lb of magnesium oxide per acre had to be given—and so on.

The book is well referenced, some 487 papers being listed, but it would have been preferable to have given a couple more pages to these so that each reference could start on a new line.

The author makes his point that more attention should be given to magnesium as a plant nutrient, and as a source of information on the relation of magnesium to the plant the book is most useful; however, a great deal of the text could be pruned with little loss. This could possibly have effected some reduction in the rather high price of this book.—D.B.M.

THE INDIGENOUS CATTLE OF THE BRITISH DEPENDENT TERRITORIES IN AFRICA

[Colonial Advisory Council of Agriculture, Animal Health and Forestry, *Publication No. 5*]

D. E. Faulkner and H. Epstein. Her Majesty's Stationery Office: London, 1957. *xviii* + 186 *pp.* (illus.) 30*s*

This monograph is of the high standard one has been led to expect from previous publications by Dr Faulkner. It presents, in logical sequence, a survey of the indigenous cattle types of Africa together with some brief preliminary observations on their origin and distribution.

The publication is more than a mere catalogue of local names and descriptions of the indigenous African cattle as already provided by Mason in his

World Dictionary of Breeds, Types and Varieties of Livestock and the basic data are presented in a very readable fashion together with notes on the environmental conditions in which the cattle are to be found and comments on their adaptation for these conditions. The value of the publication is considerably enhanced by 119 photographic plates which illustrate the breed characteristics of the livestock described.

It was perhaps inevitable that the monograph was written in 1955 and 1956, dated 1957 but not made available for publication until 18 February 1958. This time delay has resulted in the fact that the authors have had to draw upon now out-dated departmental reports for their basic data. Thus the Kenya Veterinary Department *Annual Report* most frequently quoted in the work is dated 1953. As a consequence, the list of references has certain omissions of more recent publications as well as omissions of important papers which were available for study at the time the publication was being written as, for instance, KIKULE's paper (1953) on ' Age changes in the teeth of Zebu cattle ' and FRENCH's paper (1955) on ' Cattle breeding problems in Uganda '.

A publication surveying the whole African scene can never obtain complete accuracy in every detail, but it is surprising to note that one or two elementary mistakes have been allowed to pass through Her Majesty's Stationery Office. Thus on page *xii* of the introduction, the principal African tribe of Uganda is spoken of as ' The Buganda ', whereas the correct ethnological term is ' The Baganda '. However, as the authors use the phrase ' The Chagga ' to describe the tribe found in the Kilimanjaro region of Tanganyika perhaps the term ' The Ganda ' would have been more acceptable. Once again the authors use the incorrect term ' Bukedi ' to describe the stock found in the Bukedi district of the Eastern Province of Uganda. The term ' Nkedi ' should have been employed. Again on page 39, the authors give the cattle population of Tanganyika as 7 000 000 whereas the detailed data presented on page *xviii* of the introduction give the correct number as 6 488 000 which (corrected to the nearest million) is 6 000 000 cattle and not 7 000 000.

One feels that certain sections of the monograph could have been expounded in greater detail for the benefit of the reader. Thus the brief comment on dwarfing presented on page *xi* of the introduction makes no mention whatsoever of the possibility that the diminution in size of all forms of African livestock is possibly due to a pituitary hypoplasia mutation which has been selected for study under African conditions owing to the resultant animals' larger proportion of surface area per unit body weight. This argument has been advanced by Epstein in original papers on several occasions and might have found mention in this monograph. Again on page *xiii* of the introduction the authors state without sufficient qualification that African cattle differ from European breeds by having coat colours which reflect the maximum amount of solar radiation. This observation is disproved time and time again in subsequent pages where the authors describe many breeds of African cattle with a large proportion of pure black beasts, e.g. Nandi cattle as kept at Baraton in Kenya.

However, the above criticisms are mainly minor ones and do not detract in any way from the great service which the authors have rendered to students

by the production of this very valuable monograph. One feels that Her Majesty's Stationery Office might have seen their way to providing this excellent publication with a more substantial cover. Students who will be turning the pages for reference will soon find they have to send this publication to the binders.—P.N.W.

OBITUARY

O. T. Faulkner, C.M.G., B.A., Dip. Agric.

O. T. Faulkner, who died on 14 February, was Principal of the Imperial College of Tropical Agriculture from 1938 to 1946. He will be remembered also as Director of Agriculture in Nigeria (1921 36) and Malaya (1936–38).

Odin Tom Faulkner was born in 1890 and graduated at Cambridge with first class honours in 1911, obtaining the Diploma in Agriculture in the following year. His first service overseas was in the research branch of the Rubber Growers' Association in Malaya, and this was followed by several years as Deputy Director of Agriculture at Lyallpur, Punjab.

He was appointed Director of Agriculture, Nigeria, in 1921 and held that post with great distinction for 15 years. Indeed, it is probably with Nigeria that Faulkner's name will be most closely associated in the history of the overseas agricultural service. He saw clearly the basic problems of peasant agriculture in West Africa, and pursuing a consistent policy based on the maintenance of soil fertility he steadily built up a highly efficient department and made his mark on local agricultural practice. This work firmly established his reputation as a sound agriculturist and able administrator. Its merit was recognized by his being made C.M.G. in 1928.

If Faulkner's success in Trinidad was less patent one has only to glance at dates to see why. He was, in fact, highly successful in making the best of very difficult circumstances; and the shape of the College today owes more to him than may be generally recognized. He came at a time of mingled hopes and fears, the hopes based on an imminent visit by a Royal Commission to the West Indies and the fears engendered by the international situation. Convinced, himself, that the College had an increasingly important part to play in the future of the West Indies, as well as more widely, he laid emphasis on legitimate hopes and worked steadily for their realization through all the inevitable delays and frustrations of the war years. His practical optimism heartened and inspired the staff.

One of his first major tasks was to coordinate the efforts of the staff in preparing evidence for the Royal Commission, and having stimulated a comprehensive plan of expansion he supported it with all his power. The Royal Commission's report, when it appeared, was favourable to the College: but by that time war had broken out and it was clear that expansion depending on re-organization of agricultural research in the West Indies would have to wait for better times. In the end it had to wait longer than Faulkner's term of office lasted. The postponement of action did not stop the continuous discussion of plans for post-war development, however. Throughout his Principalship Faulkner was engaged in planning, or in persuading the authorities at home and in the West Indies to policies that he thought were in the interests of the Imperial College of Tropical Agriculture. Immediately on his retirement there was little to show for all this patient and careful work, but it has borne fruit since.

Meanwhile, of course, the war brought its difficulties in the day-to-day running of the College; but these Faulkner took in his stride and met with unfailing resource and courage. All essential functions went on, and there

was progress. The College took its share in various voluntary activities, including Red Cross work, Civil Defence, Special Police, and a ' grow more food ' campaign. All these the Principal helped and encouraged.

In character Faulkner exemplified all that one understands by integrity. He was open-minded in his approach to questions, thorough in their examination, and forthright and tenacious in action when satisfied about the right course to follow. Always straightforward and sincere, he was completely loyal to colleagues and inspired loyalty. In staff relations he preferred to guide with a minimum of interference, trusting his officers to do their jobs and leaving them as far as possible both the initiative and the credit, though always ready with advice or help if either was needed.

He retired as he did other things—thoroughly. This was partly due to his passion for yachting, which took him away from any temptations towards armchair agriculture. His first concern on retiring was the building of a yacht on which he and Mrs Faulkner made their home for several years. More recently, however, they had come ashore and built a house in Norfolk, where the yachtsman had turned gardener.

We respectfully extend sympathy to Mrs Faulkner and to his and her sons. In so doing we are mindful that Mrs Faulkner, too, gave of her best to College life and the war effort during her husband's Principalship.

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Flora of Trinidad and Tobago: This Flora, which has been issued irregularly in parts since 1928, is a compilation of the work of many authors. The early parts, mainly by R. O. WILLIAMS, were edited by the Department of Agriculture of Trinidad and Tobago, but since the end of the 1939–45 war editing has been taken over by the Botany Department of the Imperial College. The Flora may be obtained either from the Department of Agriculture or from the Imperial College. The following parts have been published:

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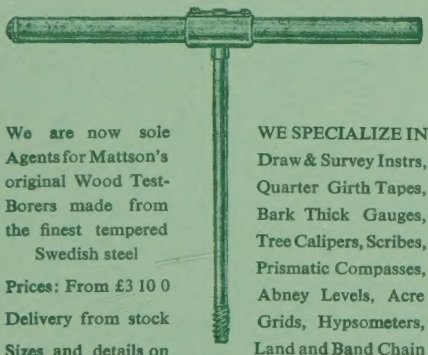

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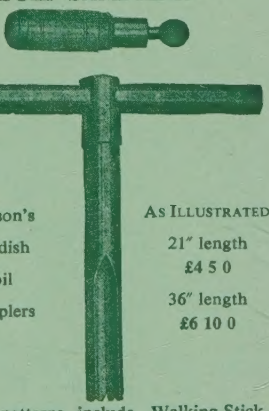

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